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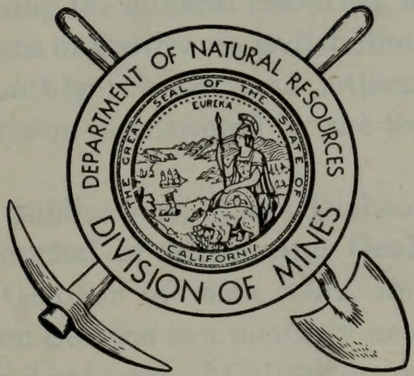

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Third Floor, Ferry Building, San Francisco 11

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The Division of Mines maintains at its headquarters offices in San Francisco a technical library containing several thousand books and scientific journals on geology, mining, mineralogy, chemistry, metallurgy, and related subjects; a reading room containing periodicals devoted to the petroleum and mining industries, and newspapers from the mining centers of the state; exhibits of minerals, rocks, mine models, etc.; a service laboratory for the determination of California minerals; and a conference room with a mining engineer in attendance to serve the public and to sell publications of the Division. Publications are also sold at the Los Angeles and Sacramento district offices.

In addition to oral conferences in the offices of the Division of Mines, information concerning the mineral resources, mineral industry, geology, and mining operations of California is distributed to the public by means of publications, monthly releases, and letters. Each letter of inquiry received by the Division is answered by the technical staff member best qualified to do so.

The principal publications of the Division of Mines are the quarterly **California Journal of Mines and Geology,** issued in January, April, July, and October of each year, and a series of **Bulletins. Mineral Information Service** is a monthly news release concerning the mineral resources and industry of California, designed to inform the public of discoveries, operations, markets, statistics, and new publications. It is distributed without cost upon request. A list of publications will also be sent free upon request.

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SUBMARINE PHOSPHORITE DEPOSITS OFF CALIFORNIA AND MEXICO

By K. O. Emery * and R. S. Dietz **

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INTRODUCTION

Phosphorite in rock dredgings from the sea floor off California was first recognized in 1937. These findings were described in two previous reports.[1] Since then, much additional material has been collected. Phosphorite has been found not only in the dredgings made by Scripps Institution of Oceanography in 1937-38, and in the earlier samples collected by F. P. Shepard and by the Coast and Geodetic Survey, but also in later samples collected by the University of California Division of War Research, the Navy Electronics Laboratory, the Scripps Institution, and the Hancock Foundation of the University of Southern California. Descriptions of the later samples have not yet been published. It is the purpose of this report to indicate the samples which contain phosphorite and to summarize other recently acquired information relating to submarine phosphorite deposits off California and Mexico.

DESCRIPTION

External Characteristics. Phosphorite occurs as nodules which vary in shape from flat slabs to irregular masses with smoothly rounded protuberances (pl. 1) that are clearly the result of accretion rather than abrasion. The nodules are firm, dense, and of medium hardness (about 5 on the Moh scale). Their surfaces are smooth, glazed, unweathered, and commonly coated by a thin film of black manganese oxide which obscures the internal structure. Cavities drilled by boring organisms are common. These tend to ''heal'' by filling with limy debris and by further deposition of phosphorite. Most nodules from any particular locality resemble each other. For example, those from Thirty Mile Bank are typically large, dark brown, and contain numerous enclosed fragments of igneous rocks, whereas those from the Santa Monica shelf are small, black, and contain little detrital material. In addition to its occurrence as nodules, the phosphorite coats some detrital rocks and permeates others.

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* University of Southern California, Los Angeles, California.

** U. S. Navy Electronics Laboratory, San Diego, California. Manuscript submitted for publication April 1949.

[1] Dietz, R. S., Emery, K. O., and Shepard, F. P., Phosphorite deposits on the sea floor off southern California: Geol. Soc. America Bull., vol. 53, pp. 815-848, 1942.
Emery, K. O., and Shepard, F. P., Lithology of the sea floor off southern California: Geol. Soc. America Bull., vol. 56, pp. 431-478, 1945.

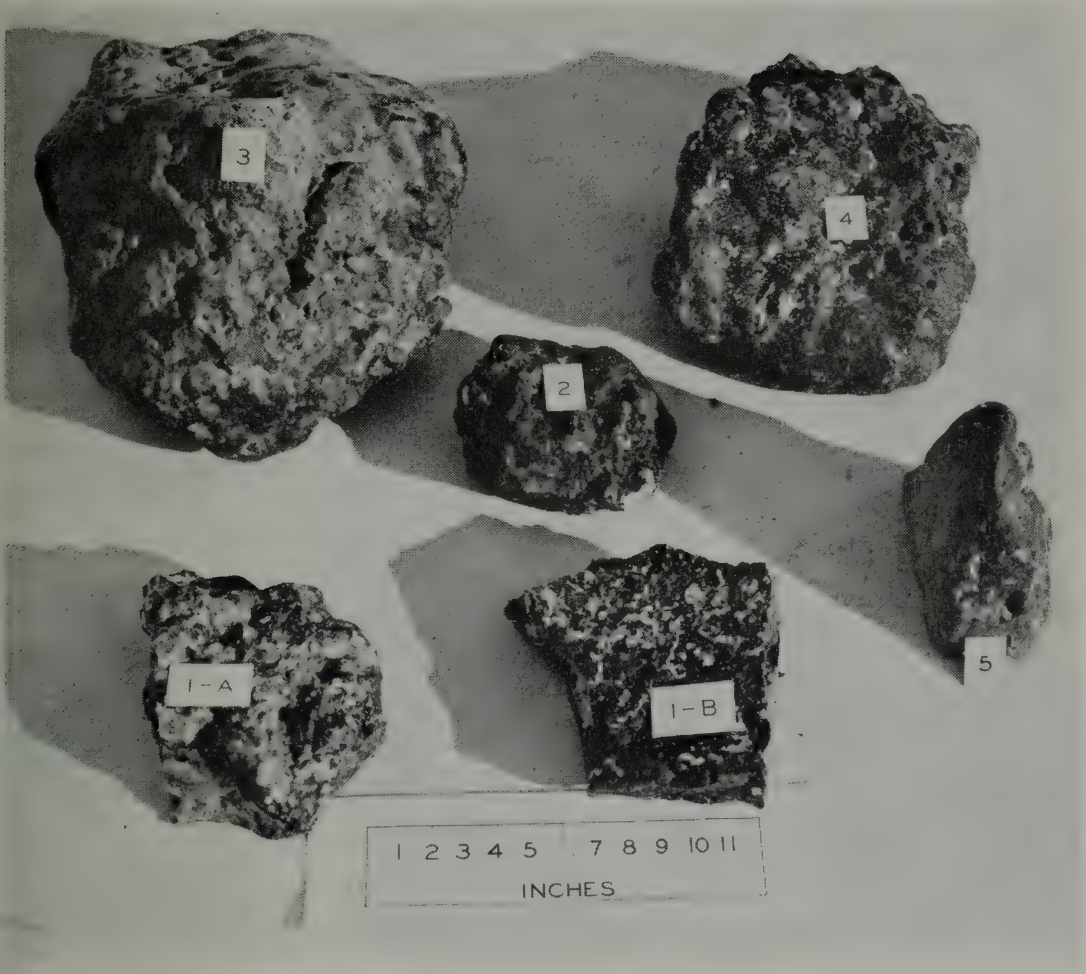
On the sea floor most of the nodules are partly buried in sediment. The exposed upper surface can be identified by the thin dark coating of manganese oxide deposited during an interruption in phosphate deposition. Some nodules have a plano-convex shape with the convex side uppermost. The tops of many nodules also have numerous attached organisms including solitary corals, bryozoans, serpulid worms, brachiopods, tunicates, and sponges. The buried bottom sides usually are barren or have only serpulid worm tubes.

Internal Structure. Fractured surfaces of the phosphorite vary in color from light brown when pure to almost black when high percentages of manganese oxide or organic matter are present. Although some of the nodules are massive and homogeneous, the large majority are layered. The layers are irregular, non-concentric, and range in thickness from a few millimeters to a few centimeters. Near its top each layer grades to darker phosphorite which ends in a glazed surface that may be covered by a thin black film of manganese oxide. These films clearly represent time intervals during which the growth of the nodule was temporarily arrested. Above the glazed surface or the film the next layer begins with an abrupt change to lighter color. Some of the layers contain many fragments of igneous, metamorphic, or sedimentary rocks including pieces of earlier phosphorite.

Examination of polished sections shows that in addition to the layers and the rock fragments most of the nodules contain numerous oolites composed of concentric layers of phosphorite (pl. 2*A*). Some of the oolites have clearly identifiable nuclei consisting of foraminiferal tests, glauconite, or clastic mineral grains. Other foraminiferal tests are directly cemented into the nodules. Although a few tests are composed of unaltered calcium carbonate, most are replaced by calcium phosphate. Invertebrate remains other than foraminiferal tests are present but not common; these include fragments of corals, bryozoans, and diatoms. Associated or incorporated vertebrate remains include sharks' teeth, a turtle plastron, whales' earbones, and other miscellaneous bones of fish and sea mammals.

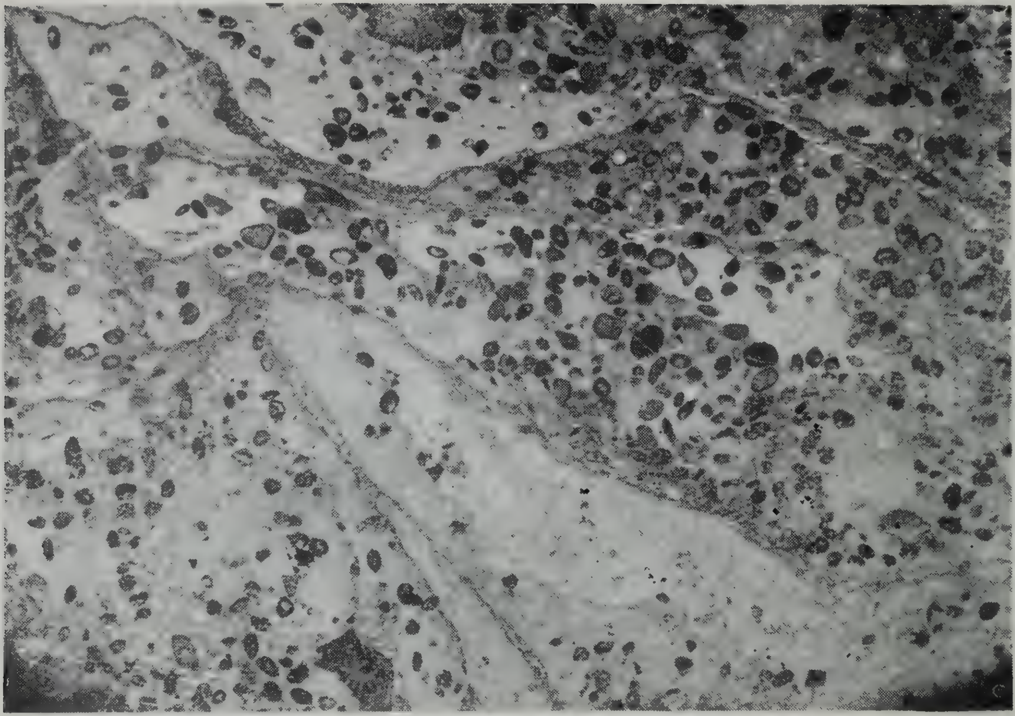
Insoluble residues obtained by digesting relatively homogeneous nodules in nitric or hydrochloric acid make up from 6 to 30 percent of the sample. Clastic mineral grains and rock fragments are extremely abundant in some residues but are absent in others. Some mineral grains are sub-rounded, but most are angular. They consist mainly of feldspar, quartz, and ferromagnesian minerals. Glauconite is abundant and occurs chiefly as rounded grains and fillings of foraminiferal tests. In addition, the insoluble residues contain amorphous silica, carbonaceous material, and siliceous organic remains such as diatoms, radiolaria, and sponge spicules. The composition of the insoluble residues is generally similar to that of insoluble residues of the loose sand associated with the nodules.

Composition.—Petrographic examination of thin sections and powdered fragments in index oils shows that the nearly isotropic collophane is the principal phosphate mineral. Associated with the collophane is an

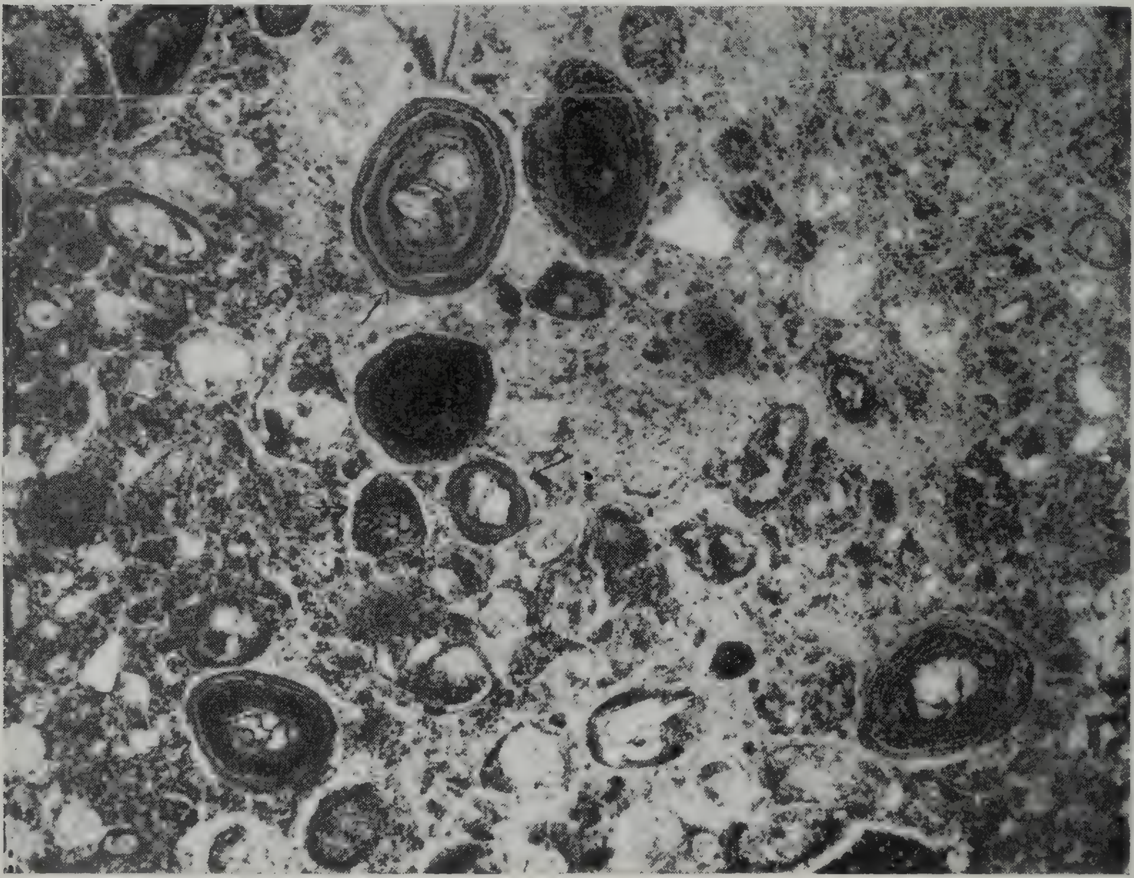


SEA FLOOR PHOSPHORITE NODULES

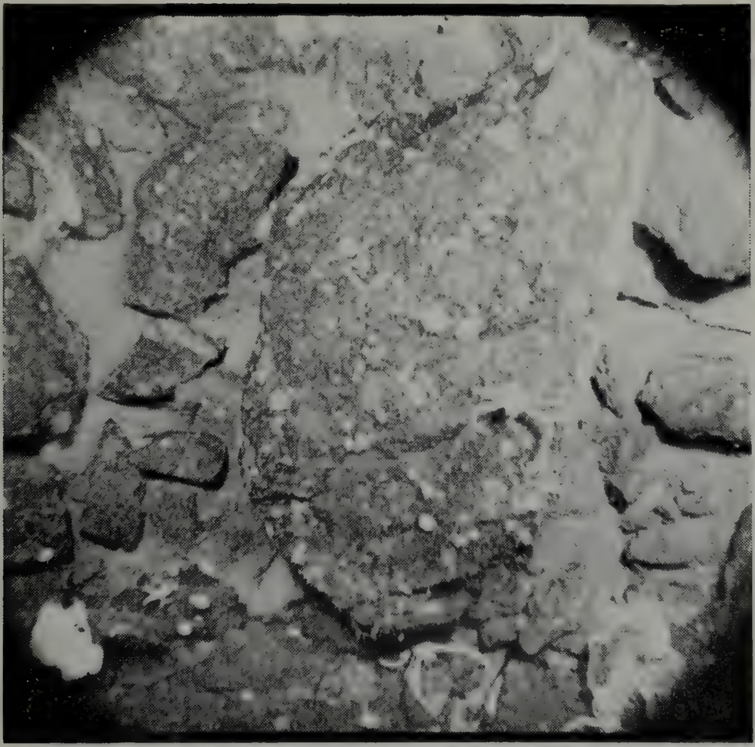
This photograph shows typical external character of nodules. Numbers 1A and 1B are top and bottom views respectively of portion of the same nodule, which has been broken. Note the difference in the type of attached organisms and protuberances. Number 2 has a black coating of manganese oxide. Numbers 3 and 4 are characteristic large nodules. Number 5 is a portion of a cut and upended nodule showing the plano-convex form typical of the larger nodules. The convex side is the side upon which active growth by accretion has taken place. Most large nodules were found with the convex side up (that is, in growth position), as indicated by attached organisms and the mud line. This suggests that they have formed in situ. *Official U. S. Navy photograph.*



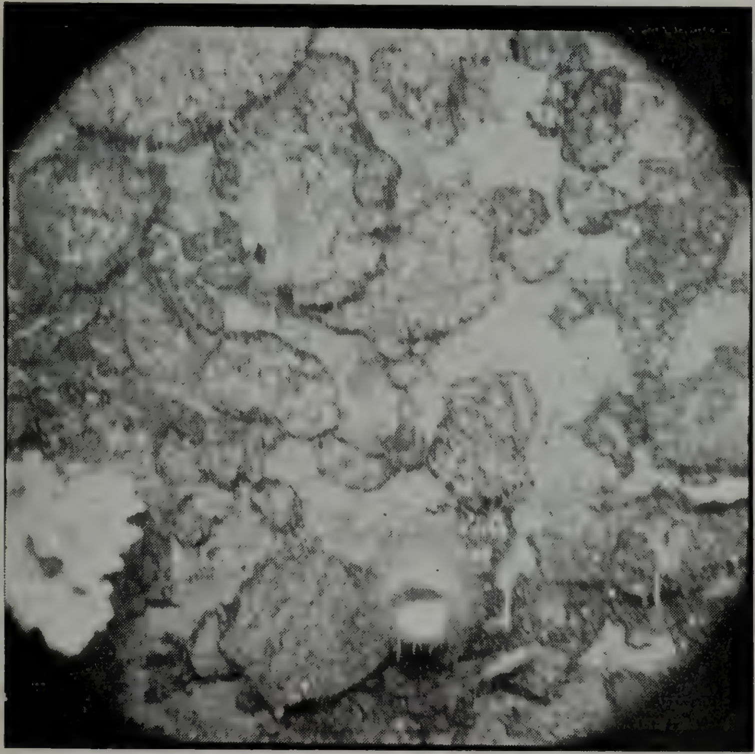
A, PHOTOMICROGRAPH OF POLISHED SECTION OF NODULE
Dredged from 200 fathoms, from bank 30 miles west of San Nicolas Island. Shows numerous enclosed oolites and mineral grains. Irregular layering indicates many discontinuous periods of accretion. x2½.



B, PHOTOMICROGRAPH OF THIN SECTION OF NODULE
From Forty Mile Bank. Shows typical texture and concentric structure of oolites. Nuclei consist of foraminiferal tests or mineral grains. An anisotropic phosphate mineral, probably francolite, forms light-colored rings of the oolites, and is scattered through groundmass. Under transmitted light, x28.

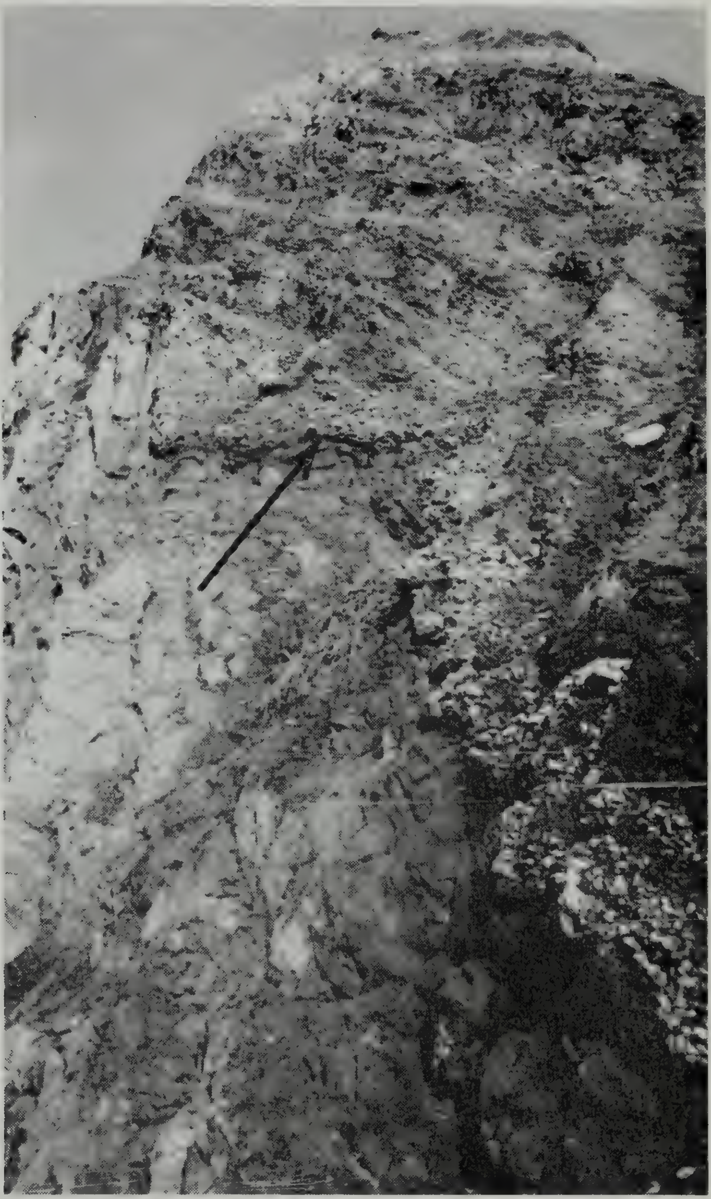


A, UNDERWATER BOTTOM PHOTOGRAPH SHOWING ONE LARGE PHOSPHORITE AND OTHER SMALLER ONES FROM THIRTY MILE BANK



B, UNDERWATER BOTTOM PHOTOGRAPH SHOWING A BED OF PHOSPHORITE NODULES FROM FORTY MILE BANK

Photo A, Note rich benthos such as a starfish, a lobster-like crustacean *(Galathea californiensis)*, and many attached organisms including sponges, bryozoans, and brachiopods. Photo taken at 140 fathoms, lat. 32° 44′, long. 117° 47′. Area shown is 4 by 4 feet. *Official U. S. Navy photograph.* Photo B, Note the two large sponges. Bottom photography has established the presence of an extensive deposit covering at least several square miles, and probably many tens of square miles, on the slopes of Forty Mile Bank. Phosphorite appears to be entirely absent from the flat top of Forty Mile Bank, which appears to be a wave-cut surface with a maximum depth of 58 fathoms, probably formed by the lower sea level of the last glacial epoch (Wisconsin). In addition to being based upon photos such as this, the identification of this phosphorite deposit is based on dredge hauls which contain nothing except phosphorite nodules, on snapper samples taken simultaneously with photos, and on color photos which show typical brown glazed surfaces of nodules. Photo taken at 90 fathoms, lat. 32° 39′, long. 117° 57′. Area shown is 4 feet by 4 feet. *Official U. S. Navy photograph.*



PHOTOGRAPH OF SEA CLIFF ON WEST SIDE OF PALOS VERDES HILLS, CALIFORNIA

Arrow points to unconformity in Miocene strata, between Valmonte diatomite and the overlying Malaga mudstone, along which phosphorite nodules are found.

anisotropic phosphate mineral which is probably francolite, although it may possibly be dahllite. This mineral is present as fibrous concentric rings in and around oolites, as small grains disseminated throughout the collophane and as a replacement of foraminiferal tests and other limy particles (pl. 2*B*). Although collophane and francolite are probably similar chemically they differ optically in type of crystallinity and in other physical properties; hence they are regarded as different minerals. In most respects the difference between collophane and francolite is analogous to that between chalcedony and quartz.

The average chemical composition of nodules from six different stations from areas off California is presented in table 1. The original six analyses are quite uniform. For comparison, table 1 also presents the average composition of phosphorite from other parts of the world. It is apparent that the California sea-floor material is as rich in phosphate as the commercially worked land deposits. The high fluorine content shows that the phosphate minerals are fluorapatites rather than hydroxyapatites. It is well known that the fluorine content in phosphorite is considerably higher than in unaltered bone. The difference between the total percentage of each analysis and 100 percent is due to insoluble residue and to soluble materials not reported in the table, such as MgO and soluble SiO_2. Small amounts of a number of trace elements are common in phosphorite as compared to other rocks.[2] Radioactivity counts of beta rays on 10 nodules from areas off California showed a range from 41 to 65 counts per minute per gram when the background was 22 counts per minute.

Table 1. Composition of phosphorite.

	Sea Floor		Land				
	California[1]	Agulhas Bank[2]	Idaho[3]	Florida[4]	Russia[5]	Tennessee blue[6]	Bone[6]
	(6) *	(2)	(4)	(4)	(10)	(1)	(1)
CaO	44.9%	40.2%	48.0%	36.4%	27.9%	45.4%	51.0%
R_2O_3	1.5	4.0	1.2	12.7	3.5	4.6	0.1
P_2O_5	28.1	21.7	32.3	31.3	17.9	31.0	38.5
CO_2	4.4	11.4	3.1	2.2	3.7	2.2	1.5
F	3.1	----------	0.5	2.0	2.0	3.8	----------
org. m.	1.1	----------	----------	6.2	3.2	3.8	8.3
	83.1%	77.3%	85.1%	90.8%	58.2%	90.8%	99.4%

* Number of analyses averaged together.

[1] Dietz, R. S., Emery, K. O., and Shepard, F. P., Phosphorite deposits on the sea floor off southern California: Geol. Soc. America Bull., vol. 53, p. 821, 1942.

[2] Murray, J., and Renard, A. F., Deep sea deposits, H. M. S. Challenger, Scientific Results, London, p. 133, 1891.

[3] Mansfield, G. R., Geography, geology, and mineral resources of part of southeastern Idaho: U. S. Geol. Survey, Prof. Paper 152, p. 210, 1927.

[4] Clarke, F. W., The data of geochemistry (5th ed.): U. S. Geol. Survey Bull. 770, p. 533, 1924.

[5] Bushinsky, G. I., Structure and origin of the phosphorites of the U. S. S. R.: Jour. Sedimentary Petrology, vol. 5, no. 2, pp. 81-92, 1935.

[6] Hendricks, S. B., Hill, W. L., Jacob, K. D., and Jefferson, M. E., Structural characteristics of apatite-like substances and composition of phosphate rock and bone as determined from microscopical and x-ray diffraction examinations: Ind. and Eng. Chem., vol. 23, pp. 1413-1418, 1931.

---

[2] Jolibois, P., and Hebert, C., Sur la composition chimique des phosphates de calcium naturels: Acad. Sci. Paris Comtes rendus, tome 222, no. 11, pp. 569-572, 1946.

Because collophane is nearly isotropic, it was, for a long time, erroneously thought to be amorphous. However, x-ray diffraction patterns show that both submarine and land phosphorites are microcrystalline and give a typical apatite powder pattern. This pattern is common to both collophane and francolite.

FOSSIL CONTENT

Many of the nodules contain identifiable foraminifera, which are best shown in polished sections or thin sections of the rock. The foraminifera in nodules from about twenty stations were identified by M. L. Natland. Nodules from twelve stations contained diagnostic forms of middle Miocene and those from three stations had species of late Miocene age. The foraminifera of four other stations could be identified only as being of Miocene age. It is noteworthy that nodules having Miocene foraminifera are found in the Gulf of California and Monterey Bay as well as in the more densely sampled area off southern California. Phosphorite containing fossils of this age is characterized by a dark brown color. A large percentage of the pieces of phosphorite lacking identifiable fossils are also of this color and, therefore, are believed to be unfossiliferous phases of material having the same history. Six samples contain foraminifera of indeterminate late Pliocene to Recent age. The material containing this fauna is usually light brown or buff and occurs as healed pholad borings, as matrix material in conglomeratic phosphorite, as outer layers on some of the larger nodules, and as small nodules. Nodules from one station contain a mixed Miocene to Recent fauna.

The sand associated with the phosphorite on the banks contains numerous Recent foraminifera and some reworked ones, mostly of Miocene age. This mixture is reasonable because fossiliferous Miocene shales and mudstones occur with the phosphorite at many places. The bones of fish and sea mammals commonly present in or with the phosphorite have not been found to be of diagnostic age.

DISTRIBUTION

Phosphorite similar to that found off California has long been known from collections made on Agulhas Bank off South Africa[3] and from several other localities on the sea floor.[4] It doubtless exists at many other places where sampling operations have not yet been undertaken, or where it has been misidentified as black or brown chert or limestone. It is known at present to range between Monterey Bay, near San Francisco, southward to the Gulf of California, a distance of at least 1200 miles. About 6000 bottom samples from this area have been examined. More than 5000 of them are from near-shore areas of rapid deposition, from the bottom of mud-filled basins, or from the deep-sea floor. Samples from such environments contain no nodular phosphorite. The remaining samples are from the tops and sides of offshore banks or from the rocky outer edge of the continental shelf. About 125 of them contain phosphorite ranging in size from small oolites to large nodules weighing more than 150 pounds. From ten of these stations almost a ton of phosphorite was recovered. In recent years many underwater photographs have been taken off California. Although one cannot identify with certainty the kinds of rock from such photographs, plates 3*A* and 3*B* were taken in areas from which much phosphorite has been dredged, and the nodular shapes of many of the rocks are suggestive of phosphorite.

---

[3] Murray, J., and Renard, A. F., Deep sea deposits, *H.M.S. Challenger,* Scientific Results, London, p. 133, 1891.
Cayeux, L., The phosphate nodules of Agulhas Bank, South African Mus. Ann., vol. 31, pp. 105-136, 1934.

[4] Agassiz, A., Three cruises of the Blake: Mus. Comp. Zool. Bull., vol. 14, pp. 281-282, 1888.
Collet, L. W., Les depots marines, pp. 194-213, Paris, 1907.

Associated with the phosphorite is a thin patchy cover of sand composed of glauconite, shell fragments, foraminiferal tests, and detrital sand grains probably mostly derived from local rock outcrops. This sand commonly includes a small percentage of phosphatic pellets, or oolites, which, because of their small size, probably have been overlooked in many samples. The associated sand is so characteristic in its appearance and composition that it could be appropriately called *bank sand.* In addition to this sand, fragments of igneous, metamorphic, and other sedimentary rocks are commonly associated with the phosphorite nodules. In some areas the size distribution of these detrital gravels is similar to that of the phosphorite nodules.[5]

The distribution chart, plate 5, differentiates between the samples containing large nodules and those having only oolites, and the many former are indicated on charts accompanying earlier reports. There is clearly a close relationship of phosphorite to submarine topographic highs. The great abundance of phosphorite localities off southern California largely reflects the greater intensity of sampling operations there.

On land, phosphorite is reported from strata ranging in age from Cambrian to Pleistocene. Much of it occurs just above unconformities, where it is associated with glauconite and fragments of marine shells; consequently, many geologists consider it a useful indicator of diastems or nonconformities.[6] The best known deposits of the United States are those of Ordovician and Mississippian age in Tennessee,[7] of Mississippian and Permian age in Idaho, Montana, Utah, and Wyoming,[8] and of Miocene and Pleistocene age in Florida.[9] There are other large deposits in Tunis, Algiers, Russia [10] and elsewhere.[11] Only a minor amount of phosphorite has been found in California. Near Monterey Bay in northern California, it occurs as thin plates in Monterey Miocene shales.[12] In southern California small tan and gray phosphatic nodules are present in outcrops and core samples of the Altamira shale, the Valmonte diatomite, and the Malaga mudstone, all of middle or upper Miocene age.[13] In nearly all instances the nodules are thin and platy, unlike those on the present sea floor. Some of the Miocene shales also are phosphatic and brown colored. However, abundant large nodules similar to those from the sea floor occur at an unconformity between the Valmonte diatomite and the overlying Malaga mudstone at the sea cliff on the northwest side of the Palos Verdes Hills (pl. 4). This interesting locality was shown to the authors by N. M. Bramlette. Similar large nodules of phosphorite were found at Lomita quarry in a matrix of glauconitic foraminiferal sand, comprising the Pleistocene Lomita marl, which lies unconformably on the Pliocene siltstone. Fairly large nodules, as much as 8 inches long, were also found at Newport Bay, where they form part of a marine conglomerate resting upon Monterey Miocene shales. These three localities, indicated on the map (pl. 5) south of Los Angeles by dots, are the only places on land in California known to the authors where large phosphorite nodules similar to those of the sea floor are present.

---

[5] Emery, K. O., Submarine geology of Ranger Bank, Mexico: Am. Assoc. Petroleum Geologists Bull., vol. 32, no. 5, pp. 790-805, 1948.

[6] Goldman, M. I., Basal glauconite and phosphate beds: Science, new ser., vol. 56, pp. 171-173, 1922.

[7] Smith, R. W., Geology and origin of the phosphate deposits of Tennessee: Eng. and Min. Jour., vol. 132, no. 1, pp. 58-64, 1931.

[8] Mansfield, G. R., Geography, geology, and mineral resources of part of southeastern Idaho: U. S. Geol. Survey, Prof. Paper 152, p. 210, 1927.

[9] Mansfield, G. R., Phosphate deposits of the United States: Econ. Geology, vol. 35, no. 3, pp. 405-429, 1940.

[10] Bushinsky, G. I., Structure and origin of the phosphorites of the U. S. S. R.: Jour. Sedimentary Petrology, vol. 5, no. 2, pp. 81-92, 1935.

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[13] Woodring, W. P., Bramlette, M. N., and Kew, W. S. W., Geology and paleontology of Palos Verdes Hills, California: U. S. Geol. Survey, Prof. Paper 207, pp. 14-40, 1946.

ORIGIN

Apatite, $Ca_5(F,Cl)P_3O_{12}$, is a common accessory mineral of most igneous rocks. On decomposition of these rocks the phosphorus is carried in solution to the ocean. There it serves as an important nutrient salt or ''fertilizer'' because it is an essential constituent of protoplasm and bones. The number of marine organisms and the rate of production in the euphotic surface waters is largely controlled by phosphate because phosphate and nitrate, another nutrient, are usually present in minimal quantities. Generally, the phosphate taken by plants and animals is soon returned to the water by bacterial regeneration; but a small amount escapes this cycle by becoming permanently deposited on the bottom, either as organic remains buried in the sediment or by growth of phosphorite nodules. Over a long period of time, the amount of phosphate permanently extracted from the oceans probably equals the amount added to the oceans from the continents. The crux of the problem of the origin of phosphorite lies in the determination of the oceanographic conditions under which it forms.

A number of hypotheses have been proposed to account for the occurrence and distribution of the phosphorite nodules. Murray and Renard [14] suggested that they formed from phosphate-rich bottom water resulting from a catastrophic destruction of life caused by the mixing of cold and warm water masses. Blackwelder [15] and Mansfield [16] believed that phosphorite formation took place in stagnant basins containing waters so low in oxygen that growth of organisms was prevented, thereby allowing such a high concentration of phosphate that deposition could finally take place. Pardee [17] believed that the deposition of the Permian Phosphoria formation was caused by the cool climatic conditions associated with the glaciers known to have existed then. Later, Mansfield,[18] recognizing the high percentage of fluorine in phosphorite, considered that it might aid in deposition. Because fluorine is common in volcanic gases, he maintained that times of intense volcanism are favorable to the deposition of phosphorite.

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[14] Murray, J., and Renard, A. F., Deep sea deposits, *H.M.S. Challenger,* Scientific Results, London, p. 133, 1891.

[15] Blackwelder, E., The geologic role of phosphorus: Am. Jour. Sci. Proc., 4th ser., vol. 42, pp. 285-298, 1916.

[16] Mansfield, G. R., Geography, geology, and mineral resources of part of southeastern Idaho: U. S. Geol. Survey, Prof. Paper 152, p. 210, 1927.

[17] Pardee, J. T., The Garrison and Philipsburg phosphate fields, Montana: U. S. Geol. Survey Bull., vol. 640, pp. 195-228, 1917.

[18] Mansfield, G. R., The role of fluorine in phosphate deposition: Am. Jour. Sci., vol. 238, pp. 863-879, 1940.

The extensive submarine deposits of phosphorite off California and Mexico present an excellent opportunity to study many of the oceanographic conditions under which phosphorite was deposited because, although much of the phosphorite is probably Miocene, some is apparently still forming at present. An examination of the concentration of phosphate in deep ocean water [19] has suggested that it is supersaturated with tricalcium phosphate; therefore, a colloidal phase of some phosphate compound may exist in equilibrium with a dissolved phase. Under this condition it is likely that slight changes in the physical-chemical environment can cause intermittent deposition of phosphorite.

Judging from the character of the submarine phosphorites, the following two facts appear to be among those which are especially important in determining the locus of deposition of phosphorite:

(1) Phosphorite is most abundant in otherwise nondepositional areas such as offshore banks, steep slopes, and the outer edge of the shelf near a break in slope. Bottom currents are concentrated in these environments so that any sediment that reaches them is soon removed and no permanent deposition takes place.[20] In such environments, the slow accretion of phosphorite may take place unmasked by clastic sediment.

(2) Phosphorite is probably confined to regions where there is high organic production in the surface waters so that an abundance of phosphatic debris rains down upon the bottom. The regions of high organic production in the oceans are near continental margins where both upwelling and runoff from the continents bring nutrients to the surface waters. Thus, the accretion of phosphorite probably does not take place under the blue oceanic waters but only under the highly productive neritic waters. This might account for the absence of phosphorite in areas distant from the coast from which some sediment and rock samples have been obtained: San Juan Seamount, Erban Bank and Twin Bank between California and Hawaii, and atolls of the Marshall Islands.

Examination of the submarine phosphorites shows that their growth by accretion is such an extremely slow and intermittent process that fossils of different ages are sometimes incorporated in the same nodules. Once a center of attraction is available, further growth of a nodule may take place through the attraction by molecular forces of like colloidal particles in a process analogous to crystal growth. Inasmuch as colloidal particles rather than ions are involved, a microcrystalline nodular mass of unoriented colloidal particles develops, rather than a crystal. Foraminiferal tests, originally of calcium carbonate, which are incorporated gradually, undergo ionic replacement, forming macrocrystalline anisotropic phosphate minerals. Accordingly, the phosphate of the main mass of the nodules is of primary origin while that of the organic remains is a secondary replacement.

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[19] Dietz, R. S., Emery, K. O., and Shepard, F. P., Phosphorite deposits on the sea floor off southern California: Geol. Soc. America Bull., vol. 53, p. 833-836, 1942.

[20] Shepard, F. P., Non-depositional environments off the California coast: Geol. Soc. America Bull., vol. 52, pp. 1869-1886, 1941.

FORMATION

Any satisfactory hypothesis of the manner of formation of the phosphorite deposits must explain the following facts:

(1) Most sea-floor nodules contain foraminifera of Miocene age only, but some contain Pliocene to Recent species.

(2) The nodules are much more abundant on the sea floor than on the present land surface.

(3) On the sea floor, phosphorite is practically restricted to areas of nondeposition of clastic sediments, many of which are clearly erosional surfaces. On land in California similar nodules are known only from unconformities.

(4) The nodules in Miocene shales and diatomites are thin and platy, unlike those of the sea floor.

(5) The sea-floor nodules and those from unconformities on land enclose sediments similar to those surrounding the nodules.

(6) The nodules contain irregular layers separated by a film of manganese oxide, showing that accretion is discontinuous and separated by long time intervals.

(7) The orientation of the larger sea-floor nodules in growth position, their large size, and the lack of abrasion rounding suggest absence of transportation after formation.

Various possible interpretations of the origin of the deposits were discussed at length in an earlier report.[21] The chief new evidence regarding origin is the presence of a large deposit of similar nodules on an unconformity between Miocene strata. The present writers consider this a strong argument in favor of the hypothesis that the nodules have formed essentially in place from Miocene to present times. It seems probable that as a result of disastrophism initiated in the middle Miocene [22] a formerly wide continental shelf or shallow sea off southern California was broken up by extensive faulting, giving rise to the basin-and-bank topography which still exists. These basins have been the site of much post-Miocene sedimentation (as exemplified by the Los Angeles basin [23]), whereas the banks have remained essentially nondepositional highs composed largely of Miocene strata.[24] Wave-and-current action has resulted in considerable erosion of the banks by winnowing away soft shales and diatomites and leaving a residual lag gravel. The gravel probably included small phosphorite nodules of the thin and platy type now found in Miocene shales. These served as nuclei for growth of large nodules or were incorporated into large conglomeratic nodules. It is considered likely that many of the large deposits have slowly formed essentially in place on the nondepositional bank environments beneath productive surface water. Accretion took place at intermittent and favorable periods and, although much of the deposition occurred during the Miocene, it has been continuing up to the present time, as shown by both paleontological evidence and widespread distribution.

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[21] Dietz, R. S., Emery, K. O., and Shepard, F. P., Phosphorite deposits on the sea floor off southern California: Geol. Soc. America Bull., vol. 53, pp. 836-845, 1942.

[22] Reed, R. D., and Hollister, J. C., Structural evolution of southern California, pp. 43-46, Tulsa, Am. Assoc. Petroleum Geologists, 1936.

[23] Poland, J., and Piper, A. M., Geologic features in the coastal zone of the Long Beach-Santa Ana area, California, with particular respect to ground-water conditions: U. S. Geol. Survey, Water Supply manuscript, 327 pp., 1945.

[24] Emery and Shepard, op. cit.

If this hypothesis is correct, future checking should show that large nodules containing only Miocene foraminifera should be absent or at least not in growth position on erosional surfaces developed during the Pleistocene epoch, such as submarine canyons and many or most of the flat shelves and bank tops.

ECONOMIC VALUE

Most of the phosphorite from land deposits is used as fertilizer, chiefly after being concentrated to "superphosphate." Between 15 and 20 percent of it is processed in the chemical industry for military, industrial, and technical purposes. A small quantity is also used as mineral feed for livestock.[25] To a minor extent some accompanying trace elements, such as vanadium have been separated as byproducts.[26] The material from the sea floor could also be used for such purposes if it could be dredged economically, as it appears to be present in large and extensive deposits in certain localities such as Thirty Mile Bank and Forty Mile Bank. However, it is unlikely that the sea-floor phosphorite will ever be profitably worked because of the practically inexhaustible land deposits which are accessible. In 1926 Mansfield estimated that the world reserves were sufficient to last 2000 years.[27] Since that time the annual consumption has increased markedly, but so have the proved reserves. The present United States reserves of high-grade phosphate rock total at least 10,000,000,000 tons,[28] while the annual production in 1946 was about 7,000,000 tons.[29] Thus, at the present rate the United States' supply should last 1500 years. Florida has the greatest production at present, and is followed by Tennessee and the western states. No phosphate rock is mined in California, but if rich deposits were discovered they might supply local markets profitably. The 1946 average price of $4.52 per ton is far below the probable cost of mining from the sea floor.

Possibly the chief economic value of phosphorites in California may be their use as marker beds. Such use, however, is dependent on more general ability to recognize the material than is common among geologists at present. The most useful criteria are the nodular shape, internal layering, hardness, near-isotropism, field chemical tests, and association with foraminifera, glauconitic sand, and bones. The chemical test, which can be performed in the field, consists of dissolving the rock in concentrated nitric acid and then adding ammonium molybdate. Phosphate, if present, yields a yellow precipitate. The reaction can be made in a test tube, or by pouring the chemicals directly on the rock surface.[30]

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[25] Jacob, K. D., Uses of phosphates: Min. and Met., vol. 25, no. 454, pp. 488-491, 1944.

[26] Johnson, A. C., and Davis, C. W., War development proves large vanadium reserves: Eng. and Min. Jour., vol. 146, no. 4, pp. 105-107, 1946.

[27] Mansfield, G. R., Phosphate reserves ample for 2000 years: Eng. and Min. Jour., vol. 122, no. 21, pp. 810-814, 1926.

[28] Mansfield, Econ. Geology, op. cit., 1940.

[29] Johnson, B. L., and Tucker, E. M., Phosphates: Minerals Yearbook, 1946, pp. 988-1005, 1948.

[30] Hicks, W. B., Simple tests for phosphates: U. S. Geol. Survey, Mineral Resources, 1915, pp. 242-244, 1917.

GEOLOGY ALONG THE ELECTRA AND WEST POINT TUNNELS, AMADOR COUNTY, CALIFORNIA *

By John H. Wiese,** Arvid A. Stromquist,** John H. Eric,**
and C. Melvin Swinney **

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INTRODUCTION

To increase the supply of electric power obtained from the Mokelumne River, the Pacific Gas and Electric Company began the construction in 1947 of two powerhouses and approximately 11 miles of water tunnel on the north bank of the river, in southern Amador County, California.

The geology along the route of the tunnels was mapped by geologists of the U. S. Geological Survey as a part of the program of investigations of geology in California in which the Geological Survey and the California Division of Mines are cooperating. It was hoped that a study of the excellent exposures afforded by the tunnels and other excavations would shed some light on the complex stratigraphy and structural features of the rocks in nearby portions of the Mother Lode belt, the study of which is a major project of the cooperative program. The scientific results were found to be of value and will be incorporated in reports that will describe the geology of the Mother Lode. Certain features of the rocks penetrated by the tunnels are of especial interest because of their relation to engineering problems, and these features are described in this report.

The Pacific Gas and Electric Company project consists of two tunnels, each 13 feet by 15½ feet in cross-section, the West Point tunnel, 14,300 feet long, and the Electra tunnel, 43,060 feet long. The tunnels have a general southwesterly course and are nearly parallel to the river. The West Point tunnel, which takes the Mokelumne River water from the afterbay of the Tiger Creek powerhouse, extends along the north wall of the canyon at a grade less than that of the river, so that its lower portal is about 250 feet above the West Point powerhouse, located at river level near the old West Point bridge. The Electra tunnel has its

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** Geologist, U. S. Department of the Interior, Geological Survey.

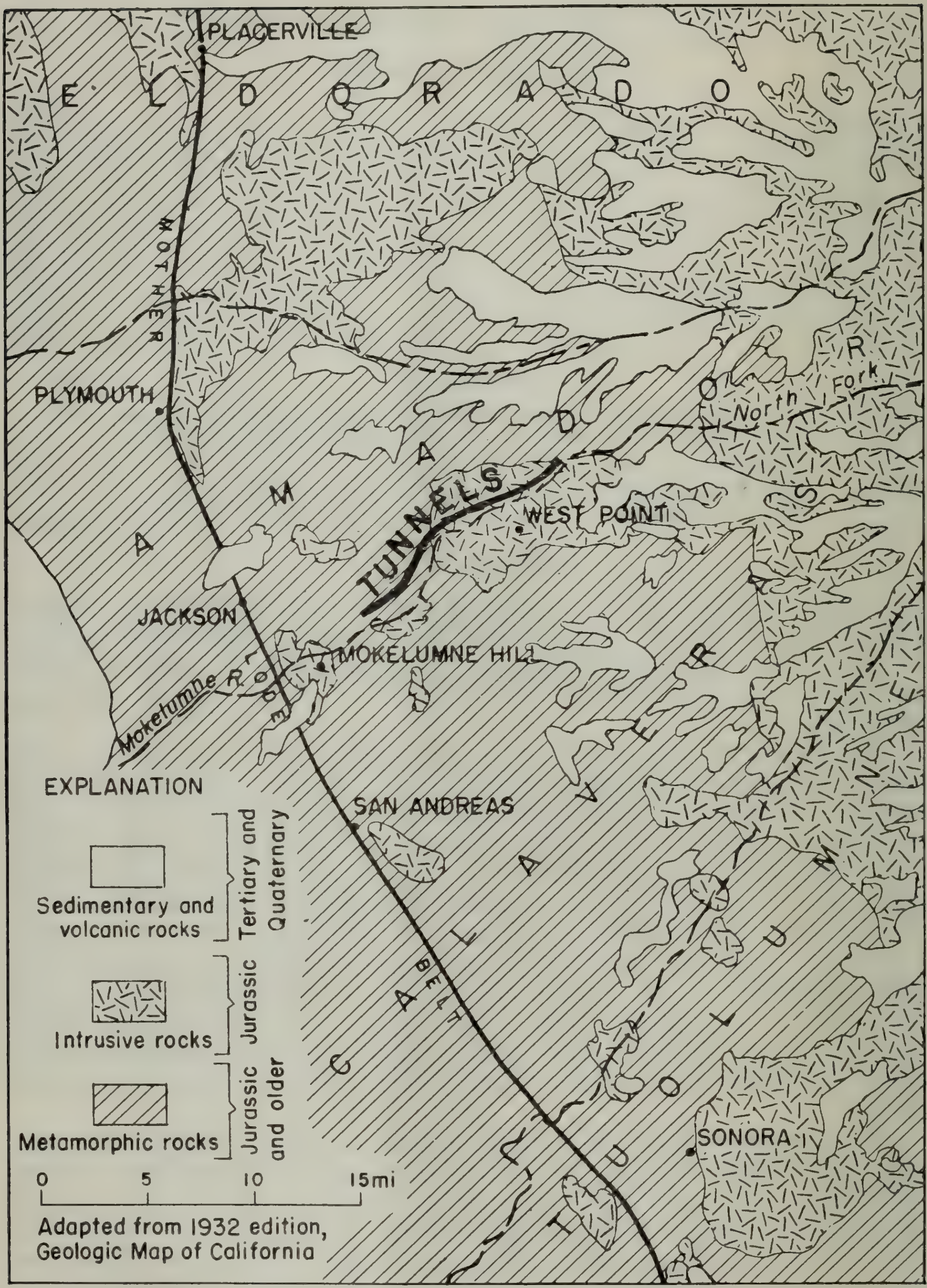
PLACERVILLE
E L D O R A D O
MOTHER
LODE
BELT
PLYMOUTH
A M A D O R
North Fork
TUNNELS
WEST POINT
JACKSON
MOKELUMNE HILL
Mokelumne R.
SAN ANDREAS
C A L A V E R A S
T U O L U M N E
SONORA
EXPLANATION
Sedimentary and volcanic rocks
Tertiary and Quaternary
Intrusive rocks
Jurassic
Metamorphic rocks
Jurassic and older
0
5
10
15mi
Adapted from 1932 edition, Geologic Map of California

FIGURE 1. Generalized geologic map of part of the Sierra Nevada, showing location of the Electra and West Point tunnels, California.

intake at the West Point powerhouse, and it also extends along the north bank of the Mokelumne to discharge into Lake Tabeaud, an artificial lake 1,200 feet above the river, from where it drops through a penstock, 7 feet in diameter at the bottom, into the Electra powerhouse. The outlet of the Electra tunnel is about 6 miles east of Jackson and 4 miles northeast of Mokelumne Hill, both of which are towns on the Mother Lode. The tunnels replace two canals, called the Standard canals, which formerly brought water directly from Tiger Creek afterbay to Lake Tabeaud. The tunnels are capable of conducting more water than the canals and, because their grade is lower, they permit the addition of the West Point powerhouse to the system.

The West Point tunnel was driven from three headings. Two headings were carried from a crosscut adit near the southwest end of the tunnel. A third heading was driven from the upper portal, at the Tiger Creek afterbay. Along the Electra tunnel line, three crosscut adits, spaced at about equal intervals, gave access to two headings each. Another heading was driven northeast from a shaft near the east end of Lake Tabeaud. Excavation began at Adit No. 2 in February 1947 and at the other workings shortly thereafter. The first segment completed was the upstream heading from Adit No. 1, which holed through early in 1948; all other excavation was finished by July.

ACKNOWLEDGMENTS

The writers are indebted to the Pacific Gas and Electric Company for permission to enter the tunnels, and to members of the engineering staff on the project for furnishing survey data and other information during the field work. Without exception, the officials and workmen of the contracting companies were generous with their cooperation. The writers are particularly grateful to Mr. Howard P. Yocum, coordinator for the three separate contractors that constructed the Electra tunnel, for his help throughout the course of the work.

GENERAL GEOLOGY

The relations of the rocks penetrated by the tunnels to those of the surrounding area are shown on fig. 1. Intrusive rocks of Jurassic age occupy most of the higher part of the Sierra Nevada; metamorphic rocks which consist of greenstone, slate, phyllite, and various types of schist lie along the foothills. Some of the metamorphic rocks are Jurassic in age, whereas others may be older than Jurassic. Sedimentary rocks of Tertiary age lap onto the western edge of the metamorphic rocks and remnants of extensive lava flows, tuffs, and breccias of Tertiary age cover parts of the metamorphic and granitic terrane far to the east.

The boundary between the granitic rocks and the metamorphic rocks is very irregular in plan, for many lobes of the intrusive rocks extend west from the main mass. One of these lobes, composed of granodiorite, is cut by the tunnels. The West Point tunnel is wholly in granodiorite and the Electra tunnel is about half in granodiorite and half in the quartz-biotite schist. Neither rock type is free of the other, however, for the granodiorite contains inclusions of the metamorphic rocks, and dikes and irregular masses of intrusive rocks penetrate the schist.

Igneous Rocks

The granodiorite is a medium-grained, light-gray rock typical of much of the intrusive rock that forms the Sierra Nevada batholith. The dominant minerals are plagioclase feldspar and biotite, and the minor minerals are quartz, potash feldspar, hornblende, and magnetite. Hand specimens seem fresh and unaltered, but under the microscope many samples are seen to contain a high percentage of secondary minerals. The plagioclase, which makes up one-half to two-thirds of the ''unaltered rock,'' is almost completely changed to fine-grained micaceous minerals, probably mostly sericite. The other minerals are altered little or not at all. Although rock altered in this way seems to retain its crushing strength and may gain in toughness, tests showed it to be unsuitable for fine aggregate because of the excessively large amount of fines produced on crushing.

The smaller igneous masses which intrude the schist range in composition from alaskite to diorite. The largest body, which is crossed by the tunnel about 1,600 feet downstream from Adit No. 3, is alaskite, a medium- to coarse-grained, light-colored rock locally containing much muscovite and generally greenish with alteration products. Pegmatite lenses and narrow sulfide-bearing quartz veins are common in the schist for several hundred feet on both sides of this intrusive. No special difficulty was encountered in driving through these rocks, though some timber was required.

Upstream from Adit No. 2, garnet-bearing, biotite-rich diorite dikes become more abundant toward the granodiorite. One wall of each dike commonly is a shear zone.

Dikes of hornblende lamprophyre intrude both the granodiorite and the schist, and they follow the general trends of the regional joints. These dikes are fine-grained, dark green, and in most places hard and flinty. Films of gouge on one or both walls are characteristic; consequently, the dikes readily break free.

Metamorphic Rocks

Most of the schist is black quartz-biotite schist, though it ranges in composition from nearly quartz-free to biotite-free. It is thinly laminated, silky on fracture planes, and intensely crenulated, individual crinkles being 1 millimeter or less in amplitude. Pyrite films are common on the joint planes and surfaces of schistosity.

Dense hornblende schist occurs in a few places between Adit No. 2 and Adit No. 3. It was the toughest rock found in either tunnel; 6 hours was needed to drill out some rounds in it. Ankerite-bearing schist is common between Adit No. 3 and the Tabeaud portal.

A highly altered schist which merits special description was encountered about 1,700 feet downstream from Adit No. 2. The rock was so soft it needed continuous support of double sets of timber, and two short segments had to be gunited before driving could proceed. Driving through about 500 feet of this schist was perhaps the most troublesome part of the project. Four feet per day was good progress. No blasting was necessary, as the face either caved in or could be picked down by hand.

This altered schist is predominantly a hydrothermally altered injection gneiss, originally composed of alternating streaks of quartz-mica schist and fine-grained, garnet-rich granodiorite, and now converted largely to sericite and other soft, flaky minerals except for a few thin beds of quartzite and dark-green ankeritic schist. Several gouge zones a few feet thick and many thinner ones were encountered. Above the tunnel there are no outcrops of the altered rock because it weathers to a soft, micaceous soil which slumps readily. The area of outcrop is traceable as a zone of landslides, springs, and dense vegetation.

STRUCTURE

Foliation

The schistosity is caused by a parallel arrangement of the mica flakes, and this foliation is the direction of easiest fracture. The schist strikes nearly parallel to the Electra tunnel along the lower 5,000 feet of its course (see pl. 6), and in this section, there was some difficulty in driving through zones of shears parallel to the foliation, which dips gently southeast. Guniting was necessary in one place where a gently dipping fault zone ran nearly parallel with the tunnel for several hundred feet.

Northeast of this segment of the tunnel the schistosity dips slightly north of east at moderate to steep angles and thus is oblique or normal to the tunnel line. In this part the rock needed support only where closely spaced joints made the schist blocky.

Throughout the granodiorite there is a steep flow banding, made apparent by the near-parallel orientation of biotite flakes and dark inclusions. At the western contact the banding strikes nearly north and dips east, parallel with the schist. Near Adit No. 1 this foliation passes through the vertical and dips west and northwest near the West Point powerhouse. The flow banding was less important than the joint planes in controlling fractures in the granodiorite.

Faults and Joints

An attempt was made to distinguish faults from joints, and both are shown on the accompanying map (pl. 1). The criteria used for faults were the presence of gouge or the offsetting of beds, dikes, or veins. It was found, however, that the joints and faults follow the same general trends and that there were all gradations between them, so their distinction on the map is rather arbitrary.

Most of the fractures are of two distinct sets. One set trends nearly north and dips moderately west; the other trends slightly north of east and ranges in dip from steeply south to vertical or steeply north. Most of the lamprophyre dikes follow fractures of the latter set. On the north-trending set, which includes most of the faults, the fault movements were generally reverse.

Fractures with other attitudes are not uncommon, and in some parts of the tunnels such fractures are dominant. For about a mile in both directions from Adit No. 2 there are prominent faults that strike slightly west of north and dip 60° to 85° E. In the first few thousand feet downstream from Adit No. 1 there are several joints and narrow lamprophyre dikes which strike north and dip 15° E.

RELATIONS OF GEOLOGY TO ENGINEERING PROBLEMS

The rate of driving of the tunnels was better in the granodiorite than in the schist. A rate of 900 feet per month was considered good progress in the granodiorite and 1,034 feet was made in the month of January in the downstream heading of Adit No. 1. In the schist 600 feet per month was good progress. This difference reflects not only the easier drilling of the granodiorite, but also the added time required both to scale down the schist after blasting and to timber much of the workings. Though the Electra tunnel is half in granodiorite and half in schist, three times as much timber was required in the schist. About one-fourth of the tunnel in schist required timber, as compared with one-tenth of the tunnel in granodiorite. Many times as much timber was used as had been anticipated.

Swelling ground was encountered in the schist; in three places heavy timbering provided insufficient support and guniting was necessary. In two places downstream from Adit No. 2 the swelling ground consisted of altered micaceous injection gneiss, and in the third place, about 3,000 feet east of Lake Tabeaud, the bad ground was a wide, gently dipping gouge zone in highly micaceous schist.

At the portals the rock is weathered to a depth of a hundred feet or less, and little timbering was necessary, hence weathering of the rocks had little effect on the rate of driving.

In the metamorphic rocks schistosity and shearing parallel to it slowed the driving only where they were nearly parallel to the tunnel line. In the lower mile of the Electra tunnel, for example, there was considerable overbreak and more scaling was necessary. Through most of the tunnels the joints aided rather than hindered excavation, furnishing incipient fracture planes along which the rock broke. Where jointing was most intense some timbering was needed, and usually water was encountered. Water also came from small solution channels in limestone layers in the schist. Where the Standard canals pass above the tunnels they undoubtedly contributed to the strong flows of water obtained beneath.

AGGREGATE

The timbered portions of the tunnels were lined with concrete after excavation was complete. Tests were made of the rock on the dumps at each adit to determine its suitability for concrete aggregate. The schist could not be used because of excess sulfides and mica. The granodiorite could have been used for coarse aggregate only, because a high proportion of fines was produced on crushing.

The nearest sources of acceptable aggregate were two tailings dumps from former hydraulic operations. Nielsen's quarry, on Chili Gulch a few miles south of Mokelumne Hill, produced coarse and pea-sized gravel from crushed and screened quartz-rich tailings. The Michigan Bar quarry, a few miles west of Plymouth on the Sacramento road, furnished all the sand and a large part of the coarser aggregate.

GEOLOGY AND TUNGSTEN DEPOSITS OF THE TUNGSTEN HILLS, INYO COUNTY, CALIFORNIA *

BY PAUL C. BATEMAN,** MAX P. ERICKSON,** AND PAUL D. PROCTOR **

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	13.	Maps and section of the Western tungsten mine	In pocket

ABSTRACT

The Tungsten Hills, covering an area of about 12 square miles, lie at the eastern base of the Sierra Nevada 5 to 10 miles west of Bishop in northeastern Inyo County, California. They are composed mainly of plutonic igneous rocks ranging from hornblende gabbro to granite, which enclose small bodies of metamorphosed sediments. Structurally the Tungsten Hills are a fault block intermediate in position between the relatively upthrown Sierra Nevada block on the south and west and the relatively downthrown Owens Valley-Round Valley block on the north and east.

The largest part of the tungsten production was made between 1916 and 1919; mining since then has been intermittent. The total estimated production to the end of 1945 amounts to 125,000 units of WO_3 (tungsten trioxide). The ores are low grade (0.4 to 0.5 percent WO_3), and their exploitation has been possible because geologic, physiographic, and climatic conditions favor inexpensive mining.

The deposits are of the contact-metamorphic type and scheelite ($CaWO_4$) is the only tungsten-bearing mineral. Mining, with a few exceptions, is confined to two areas, the Deep Canyon area and the belt along the northern margin of the Round Valley pendant. In the Deep Canyon area the deposits are contained in small bodies of metamorphosed sedimentary rock that are completely enclosed in plutonic intrusive

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** Geologist, U. S. Department of the Interior, Geological Survey.

rocks. The deposits that have been explored at depth show a downward decrease in scheelite content and in the degree of additive metamorphism. These relationships suggest that the metamorphic rocks in this area are inclusions. The more intense mineralization and metamorphism in their upper parts are probably due to the imperviousness of the capping igneous rock which impeded the movement of upward-moving solutions and caused the deposition of new minerals. Two of the deposits are still partly covered by the igneous rock enclosing them.

The mines along the northern contact of the Round Valley pendant, a somewhat larger body of metamorphosed sediments, do not show any such relation between depth and degree of metamorphism and mineralization. The additive metamorphism and amount of tungsten minerals are most noticeable at the contact of the pendant with granite and diminish with distance from the granite.

Mining has been profitable only during times of exceptionally favorable market conditions, and this probably will continue to be the condition in the future. Inasmuch as the district has been prospected over a period of 30 years, it does not offer opportunities for new discoveries comparable with those in less accessible parts of the Sierra Nevada. Nevertheless, the discovery within the last few years of two moderately productive deposits is some cause for hope that others will be found.

INTRODUCTION

The Tungsten Hills (pl. 7) are at the eastern base of the Sierra Nevada 5 to 10 miles west of Bishop, in northeastern Inyo County, California. They contain the oldest of several tungsten mining districts near Bishop, mining having been carried on intermittently since 1916. The ores are moderately low in grade, but their exploitation has been materially aided by local conditions which make mining costs low. Among these are easy accessibility; low altitudes; usually mild winters and light snowfall; availability of water and electrical power; and the roughly equidimensional shapes of most of the deposits, which make them suitable for low-cost exploitation by means of glory holes.

Several roads lead into the Tungsten Hills from U. S. Highway 395, which runs northwest from Bishop along their base, and from the Bishop Creek Highway running west from Bishop. The hills are a northeast-facing salient formed by an offset in the Sierra Nevada front. They cover an area of approximately 12 square miles. Prominent escarpments mark the north, east, and west sides, but to the south the Tungsten Hills merge with Grouse Mountain and its related spurs and ridges. The surface of the hills is a gently rolling, little-dissected part of the old erosional surface that was developed across the site of the present Sierra Nevada prior to the faulting along the eastern edge of the range. The summit surface of the hills for the most part is between 5,500 and 6,500 feet above sea level, but one peak rises to 6,903 feet. In general, altitudes are highest along the western edge and decrease gradually to the east.

Although the drainage channels consist mainly of dry canyons that notch the margins of the hills, two streams, Deep Creek and McGee Creek, flow eastward from the Sierra Nevada through the Tungsten Hills to the Owens River. McGee Creek carries a good flow of water the year round, but Deep Creek flows only a few months in the spring.

According to Knopf,[1] J. G. Powning first discovered crystals of scheelite (calcium tungstate) in 1913 in the tactite outcrop at the site of the Jackrabbit mine when he picked up a rabbit he had just shot. Scheelite had been identified a year and a half earlier in gold placers along

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[1] Knopf, Adolph, Tungsten deposits of northwestern Inyo County, California: U. S. Geol. Survey Bull. 640, p. 231, 1917.

Deep Creek, but the bedrock discovery was delayed because the search was confined to the numerous small quartz veins in the area, most of which carry no scheelite.

The Standard Tungsten Company and the Tungsten Mines Company began mining operations in the Deep Canyon area in 1916 under the stimulus of the high price then paid for tungsten concentrates. These were among the earliest profitable exploitations of contact-metamorphic tungsten deposits made in the United States. Operations at the Round Valley mine were begun a short time later. Most of the production was between 1916 and 1919; mining since then has been intermittent. Accelerated activity between 1940 and 1945 resulted in a secondary peak in production. D. M. Lemmon [2] of the Geological Survey estimated that to the end of 1940 more than 100,000 units of WO_3 (tungsten trioxide) was recovered (a unit of WO_3 is 20 pounds of the contained pure material). The present authors estimate that between 1940 and 1945 about 25,000 units additional was produced, making a total estimated production to the end of 1945 of about 125,000 units of WO_3. None of the mines were operated during 1946 or 1947.

Most of the mines are in the Deep Canyon area, but tungsten deposits are also found in the northeastern part of the hills along the northern margin of the Round Valley pendant. Only a few prospects occur outside of these two areas. In 1943 and 1944, at the height of the World War II activity, mills were operating at the Aeroplane mine in the Deep Canyon area and at the Western tungsten mine at the western end of the Round Valley pendant. The former Bishop Tungsten Company mill 5 miles south of Bishop and the El Diablo Mining Company mill on Bishop Creek processed ore from the Round Valley and the Tungsten Blue mines, respectively. Ore from the White Caps mine, the Hilltop mine, and the Jackrabbit mine was milled at the Aaron J. Smith mill near Otey's Corner between Bishop and the Tungsten Hills. The tailings in Deep Canyon were reworked, beginning in 1937. This operation was begun by the Tungsten Milling Company, but was taken over first by the Tungsten City Milling Company, and later by the Tungsten City Milling Syndicate, Ltd. In addition to scheelite, garnet also was recovered and sold as abrasive. The tailings at the Round Valley mine were also reworked.

Knopf,[3] in 1917, made a preliminary report based on an examination of the deposits in 1916. His descriptions of the rocks and ores are particularly noteworthy. Hess and Larsen [4] published a description of the mines as they were in 1918 at the height of the World War I activity. Their report contains surface geologic maps of the Little Sister mine and of the Round Valley pendant. In 1939 and 1940, Lemmon [5] examined the deposits and published a report that contains preliminary maps of all the older deposits.

The present report is a summary of work done by survey geologists since 1940 and is intended to supplement Lemmon's report. In the fall of 1943, Bateman and Erickson prepared detailed maps showing the geology of the more important properties. In 1946, as part of a cooperative program between the U. S. Geological Survey and the California

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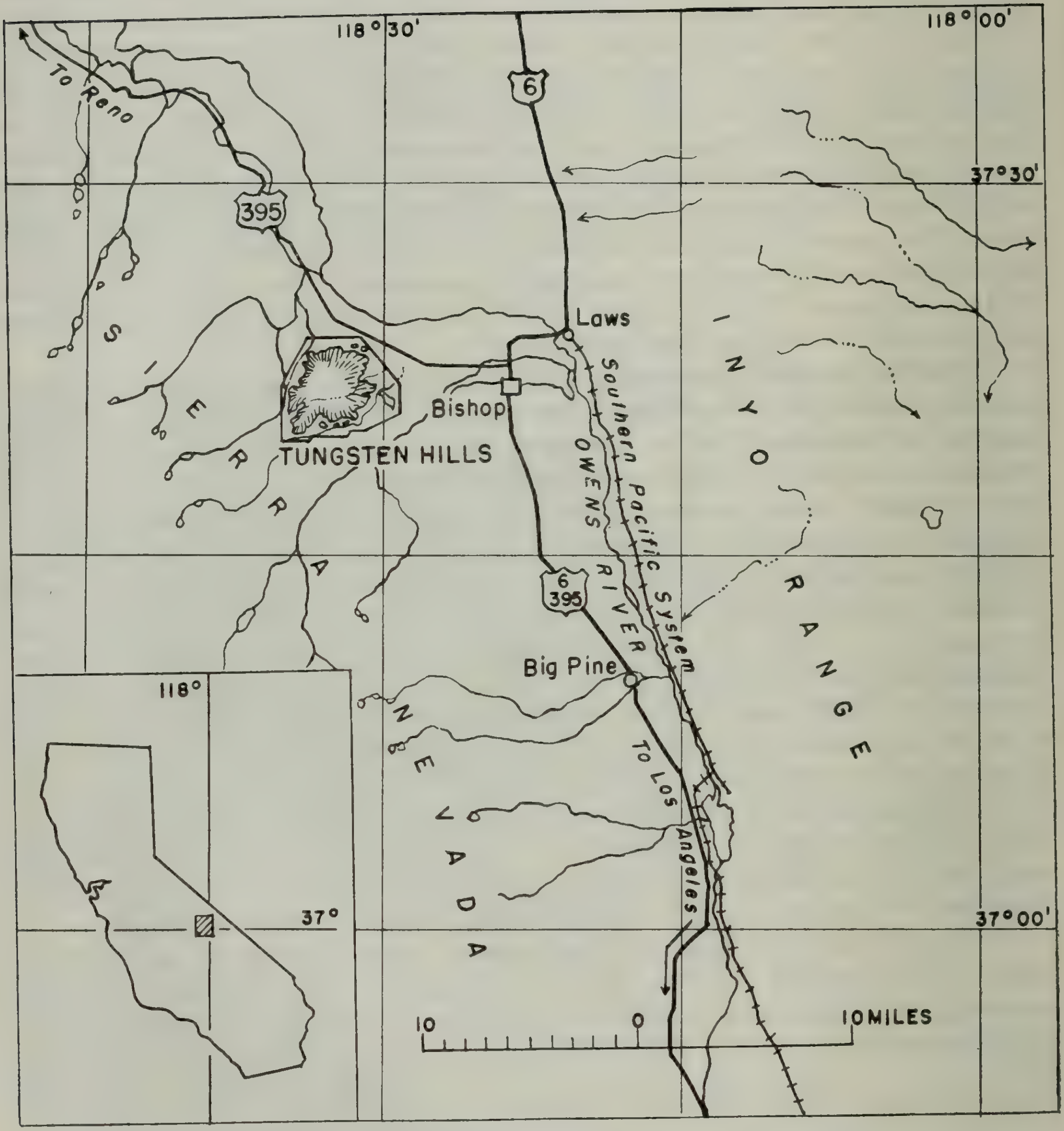
[2] Lemmon, Dwight M., Tungsten deposits in the Tungsten Hills, Inyo County, California: U. S. Geol. Survey Bull. 922Q, p. 498, 1941.

[3] Knopf, Adolph, op. cit., pp. 229-249.

[4] Hess, F. L., and Larsen, E. S., Contact-metamorphic tungsten deposits of the United States: U. S. Geol. Survey Bull. 725, pp. 268-274, 1921.

[5] Lemmon, Dwight M., op. cit., pp. 497-514.



118° 30'
118° 00'
37° 30'
37° 00'
To Reno
395
6
Laws
Bishop
TUNGSTEN HILLS
SIERRA NEVADA
INYO RANGE
OWENS RIVER
Southern Pacific System
6
395
Big Pine
To Los Angeles
118°
37°
10
0
10 MILES

FIGURE 1. Index map showing location of Tungsten Hills.

State Division of Mines, Bateman and Proctor prepared a geologic map of the Tungsten Hills (pl. 7) on a scale of 1 inch to 2,000 feet, using aerial photographs as a base.

Many operators of mining properties and residents of Bishop have been helpful in supplying information and have given assistance in other ways. The authors are also indebted to several members of the Geological Survey, particularly to D. M. Lemmon for his suggestions and criticism during the mine mapping, and for his review of the manuscript. They wish also to thank John H. Wiese, Parker Trask, Ward C. Smith, Winona Eckstein, and R. E. Van Alstine, all of the U. S. Geological Survey, for critical reading of the manuscript.

GEOLOGY

The Tungsten Hills are composed mainly of plutonic intrusive rocks of Jurassic (?) age, ranging in lithology from hornblende gabbro to granite, which enclose small blocks of metamorphosed sediments. Swarms of lamprophyre dikes also of Jurassic (?) age cut across the central part of the hills from east to west. Tertiary basalt necks and dikes form low peaks and ridges in the west-central part. Quartz dikes and masses occur locally in the plutonic rocks and most of them are associated with altered zones.

Metamorphic Rocks

The metamorphic rocks are pre-Cretaceous in age and probably include both Paleozoic and early Mesozoic rocks.

In mapping the blocks of metamorphosed sediments all of the noncalcareous metasedimentary rocks, including quartzite, schist, and hornfels, were grouped together. The calcareous rocks, being of special interest, were separated into marble, light-colored calc-silicate rock, and tactite. Most of the marble is recrystallized to coarse white calcite, but some is gray and moderately fine-grained. The typical calc-silicate rock is a dense, fine-grained rock consisting essentially of plagioclase, diopside, and garnet. The calc-silicate rock was formed mainly by the addition of material, chiefly silica, to limestone, but some may have resulted from the recrystallization of impure limestone with little or no addition of material. The typical tactite is dark and coarse grained; fine-grained varieties grade into light-colored calc-silicate rock. The mineral content varies somewhat from place to place, but garnet (andradite), hornblende, pyroxene of the diopside-hedenbergite series, epidote, chlorite, quartz, and calcite are generally present. Magnetite, sphalerite, pyrite, chalcopyrite, molybdenite, scheelite, apatite, sphene, phlogopite mica, feldspar, and idocrase are locally abundant.

Igneous Rocks

The plutonic rocks were intruded in sequence during Jurassic (?) time, successive bodies being increasingly siliceous. The oldest is hornblende gabbro, which was followed successively by quartz diorite, granodiorite, quartz monzonite, and granite. The different intrusive rocks can be easily distinguished from one another by their differences in color and grain size (see table 1). The granite is very light colored, but the quartz monzonite, granodiorite, quartz diorite, and hornblende gabbro are increasingly darker owing to larger percentages of dark minerals. The typical quartz monzonite is porphyritic. The granite, quartz monzonite, and most facies of the quartz diorite are moderately coarse-

Table 1. Summary of plutonic igneous rocks in the Tungsten Hills

Rock	Order of emplacement	Color	Granularity	Percentages of essential minerals					Accessory minerals	An. content of Plagioclase
				Quartz	K-feldspar	Plagioclase	Biotite	Hornblende		
Hornblende gabbro	1	Dark gray to black	Coarse, extremely irregular texture	none	none	40	trace	55	Augite, magnetite, sphene	Zoned 25-75
Quartz diorite	2	Dark gray	Coarse, equigranular	10-20	0-15	50	15	10-15	Magnetite, apatite	Zoned 25-68
Granodiorite	3	Medium gray	Medium, equigranular	20	15-25	45	5-15	5	Magnetite, apatite, sphene, zircon	Zoned 20-45
Quartz monzonite	4	Light gray	Coarse, usually porphyritic (phenocrysts of K-feldspar)	20-30	25-35	25-35	3-10	trace	Magnetite, apatite, zircon, allanite	Zoned 20-40
Granite	5	White, pink or buff	Coarse, equigranular	20-45	40-60	15	1-4	none	Magnetite, apatite, sphene, zircon	10

grained. Irregularity in both grain size and mineral content give the hornblende gabbro a distinctive splotchy appearance. All the plutonic rocks are jointed, but the joints are more closely spaced in the relatively finer-grained granodiorite than in the other intrusives. This closer spacing of joints in the granodiorite causes the granodiorite to break down into small angular blocks which contrast with the rounded forms produced by the weathering of the other plutonic rocks.

In the Tungsten Hills, quartz dikes and masses have been found only in quartz monzonite, but in nearby areas they occur in other intrusive rocks as well. Commonly associated with the quartz masses is a porous iron- or manganese-stained rock composed mainly of partly sericitized feldspar and muscovite. No mafic minerals and only a few corroded grains of quartz remain. It is evident that the original quartz grains have been largely replaced by mica. Limonite pseudomorphs after pyrite are common.

The main area of granite outcrop is a belt as much as a mile wide along the northeast margin of the hills. The granite is a light-colored, coarsely crystalline, equigranular rock containing biotite as the only dark mineral. Most of the individual grains fall between 0.3 and 0.8 centimeter in diameter. Weathered surfaces are buff or pale pink. Fresh specimens may have a pinkish cast owing to the color of the potash feldspars. Both orthoclase and microcline are present and are notably microperthitic. The content of potash feldspar ranges from 40 to 60 percent and quartz from 20 to 45 percent, but together they consistently make up about 80 percent of the total rock. The granite also contains 15 percent albite (An_{10}), 1 to 4 percent biotite, and 1 percent accessories (sphene, magnetite, apatite, and zircon).

Quartz monzonite underlies almost two-thirds of the hills. A few sharp contacts can be seen in the field between very slightly different types, but these contacts can never be traced very far. The most common type is somewhat prophyritic with phenocrysts of microperthitic orthoclase and microcline about 1 centimeter long. Potash and plagioclase feldspars together make up 50 to 75 percent of the total rock, generally occurring in approximately equal amounts. The plagioclase is generally zoned from An_{40} to An_{20}, but several unzoned crystals examined have compositions of An_{29}. Quartz is present is amounts ranging from 20 to 30 percent, although one specimen contained 45 percent. The biotite content ranges from 3 to 10 percent. Accessory minerals include apatite, zircon, magnetite, and allanite.

Granodiorite forms most of the northwest-trending ridge crossed by McGee Creek on the east side of the hills. Another somewhat smaller body is about 1 mile west of this ridge on the south side of Deep Canyon, and there are several small masses along the northeast edge of the Tungsten Hills north of Deep Canyon. The rock contains about 45 percent of zoned plagioclase (An_{45} to An_{20}), 15 to 25 percent potash feldspar (mostly orthoclase, but some microcline), 20 percent quartz, 5 to 15 percent biotite, 5 percent hornblende, and 2 percent accessories (magnetite, sphene, apatite, and zircon). The content of biotite in the specimens examined varied inversely with the potash feldspar content.

The quartz diorite and gabbro are closely related, and gradations may exist between them. They occur together in the Deep Canyon area, surrounded by quartz monzonite. The most typical quartz diorite contains 50 percent plagioclase, 10 to 20 percent quartz, 15 percent biotite, 10 to 15 percent hornblende, and 0 to 15 percent orthoclase or microcline. The plagioclase is commonly zoned from An_{50} to An_{25}, but small cores may be as calcic as An_{68}. Alternate and continuous zoning occur, but the latter is more common. Quartz and orthoclase commonly are interstitial.

The percentage mineral content in the gabbro is variable, but a common type contains 55 percent hornblende, 40 percent plagioclase, and 5 percent accessories (sphene and magnetite). The plagioclase, like that in the quartz diorite, is commonly zoned from An_{50} to An_{25}, but small cores were found as calcic as An_{75}. In places the gabbro contains augite or uralitic hornblende.

The lamprophyre dikes are composed essentially of plagioclase, biotite, and hornblende. Biotite and hornblende occur in variable proportion, but together usually equal the plagioclase in amount. Magnetite and muscovite are accessories. The plagioclase is strongly zoned, and ranges from An_{75} to An_{20}. The texture is usually porphyritic, but some specimens examined are equigranular. Gilbert [6] has called similar dikes in a nearby area malchites.

Structure

Structurally the Tungsten Hills comprise a fault block intermediate in position between the relatively upthrown Sierra Nevada block on the south and west and the relatively downthrown Owens Valley-Round Valley block on the north and east. Although the faults bounding the block are not visible, there is little doubt that the escarpments on the north, east, and west sides of the hills are eroded fault scarps. The depressed area to the west, between the hills and the Sierra Nevada, is a down-dropped block, or graben. To the south no break is apparent between the hills and Grouse Mountain; but Bishop Creek, south of Grouse Mountain, marks a hinge line between the relatively level Grouse Mountain-Tungsten Hills block and the north-tilted block south of Bishop Creek.

Within the hills, faulting later than the intrusions is not prominent. Three high-angle reverse faults exposed in the large glory hole and the underground workings at the Little Sister mine undoubtedly extend eastward along the lower part of Deep Canyon. However, the displacements on the faults are probably small, for the igneous contacts that cross Deep Canyon west of the Little Sister mine are not noticeably offset. A fault cutting the metmorphic block near the east end of the contact between the granite and quartz monzonite, in the northeastern part of the hills, is exposed in a prospect pit. This fault brings calcareous rocks against quartzite, but neither the direction nor the magnitude of the displacement is known.

Folds and faults older than the intrusives are evident in the pendants and inclusions of metmorphic rock. Most beds dip steeply but range from horizontal to vertical. The truncation of bedding and faults by intrusive rocks and the control of intrusions by structures in the metamorphic rocks indicate that these rocks were deformed before the emplacement of the intrusives.

The distribution of the metamorphic rocks is of particular interest because they contain the tungsten ore bodies. With a few exceptions the metamorphic rocks occur either along or near the contacts between intrusive bodies, or are enclosed within the gabbro or quartz diorite. The contact between quartz monzonite and granite in the northeast part of the hills contains the Round Valley pendant at its west end, and other blocks of metamorphic rocks are scattered along its length. Similarly, the contacts in the Deep Canyon area, between quartz diorite and quartz monzonite, contain numerous small metamorphic blocks. The quartz diorite and gabbro in the Deep Canyon area enclose many metasedimentary bodies.

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[6] Gilbert, Charles M., Late Tertiary geology southeast of Mono Lake: Geol. Soc, America Bull., vol. 52, p. 784, 1941.

The notable exceptions to the two general settings for the metasedimentary rocks are small inclusions found at the White Caps mine, at the Raindrop prospect, and southwest of the Lucky Strike mine. At all these localities metamorphic rocks are enclosed in quartz monzonite.

The authors believe that the intrusive rocks were emplaced largely at the expense of sedimentary rocks and that the fragments of metamorphic rock along contacts between intrusives are remnants, more or less in place, of the original cover. The principal evidence for this belief is that along contacts between intrusives many of the metamorphic fragments are completely or almost completely enclosed within the older intrusive, although others are in contact with both intrusives or are enclosed within the younger. These relationships suggest that the original margin of the earlier intrusive very nearly coincided with the present contact. Where remnants are missing along contacts between intrusive bodies, the younger intrusive is thought to have encroached into the older.

It follows from this hypothesis that the metamorphic bodies between intrusives are not necessarily roof pendants. Before erosion they may have been discontinuous upward, as well as laterally and downward. This concept also gives reason to believe that contacts between intrusives that have metmorphic remnants along them at the surface will contain other remnants that do not reach the surface. Exploration of these buried metamorphic bodies may result in finding new tungsten ore bodies.

The absence of inclusions in the interior of the quartz monzonite and the granite is probably due to the large size of these intrusives and their consequent slow rate of cooling which allowed sufficient time for the digestion or removal of foreign fragments acquired during their emplacement. By contrast, the smaller intrusions of gabbro and quartz diorite have not been able to clear themselves of foreign fragments.

TUNGSTEN DEPOSITS

General Relations

All of the tungsten mines but one (the Van Loon quartz-scheelite prospect) are of the contact-metamorphic type, and scheelite ($CaWO_4$) is the only tungsten-bearing mineral. The scheelite is contained in tactite, a rock generally formed from limestone or marble mainly by the addition of silica, iron, and alumina. In larger marble bodies tactite occurs as a selvage on the contacts with intrusive igneous rocks, and along certain favorable beds and structures extending from its borders into the marble. In some small bodies the tactite completely replaces the marble.

Tactite, however, does not occur along all contacts between marble and intrusive igneous rocks, and is notably irregular in thickness where it does occur. In places it pinches abruptly from many feet to an inch or less in thickness. Furthermore, scheelite is not evenly distributed through the tactite, but occurs in bunches or streaks that may attain sufficient size and grade to be ore shoots.

Genesis of the Deposits

The solutions that reacted with marble to form tactite are believed to have been derived from molten magmas which solidified to the igneous rocks. These solutions migrated upward or laterally along contacts fractured by stresses related to the cooling of the intrusive rocks. Inasmuch as calcium is necessary for the formation of lime silicates and scheelite, tactite formed most readily where the solutions came in contact with marble. The formation of tactite tended to seal fractures; as the constituent minerals did not all crystallize at the same time, repeated fracturing was necessary for the development of those containing more than a few kinds of minerals. Scheelite formed late in the development of the tactite and consequently occurs only where fracturing developed permeability during the later stages of mineralization. Sulfides, including pyrite, sphalerite, chalcopyrite, and molybdenite are associated with quartz stringers that cut all the other constituents of the tactite, indicating they were among the last minerals to form.[7]

Although tactite occurs in contact with granite, quartz, monzonite, quartz diorite, and hornblende gabbro, probably only the granite and quartz monzonite magmas supplied mineralizing solutions. Inasmuch as granite is the youngest intrusive, the tactite along its contacts must be attributed to it. Tactites in contact with the quartz monzonite, both in the Tungsten Hills and in the surrounding areas, occur at considerable distances from any outcrops of granite, suggesting that mineralizing solutions were derived from the quartz monzonite also. Evidence that some tactite bodies antedate the emplacement of the granite is found in the high Sierra to the west along the western margin of the Pine Creek pendant. There, dikes of alaskite granite cut tactite that is developed along a contact between marble and an intrusive intermediate in both age and composition between the granite and quartz monzonite. The tactite bodies enclosed in quartz diorite or hornblende gabbro all are within short distances of outcrops of either granite or quartz monzonite, and may be even closer in depth. This relationship suggests the tactite-forming solutions were derived from granite or quartz monzonite, but is not conclusive evidence.

Vertical Extent of the Ore Bodies

All the tungsten deposits in the Deep Canyon area in the southeast part of the Tungsten Hills are contained in small pendants or inclusions, whereas those in the northwest part of the hills occur along the northern margin of the Round Valley pendant, a somewhat larger block of metamorphic rocks. On the very general principle that the larger the areal extent of the metamorphic block, the deeper it will extend, the Round Valley pendant should extend deeper than any of the Deep Canyon metamorphic blocks. None of the bodies of metamorphic rock in the Tungsten Hills can be expected to extend to depths comparable to those found in the pendants crossing Bishop Creek or Pine Creek in the high Sierra.

Although an ore body can extend downward to the bottom of the metamorphic block in which it is enclosed, other factors may cause its termination at a lesser depth. Calcareous strata may not exist in the lower part of the pendant, or if present may not be converted to tactite. Even if tactite is present, it may contain little or no scheelite.

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[7] For a discussion of the factors involved in the localization of tactite bodies and tungsten ore shoots in a nearby area see: Bateman, Paul C., Pine Creek and Adamson tungsten mines, Inyo County, California: California Jour. Mines and Geology, vol. 41, pp. 231-249 (but especially pp. 241-242), October 1945.

In the Deep Canyon area several of the ore bodies die out downward. In the Little Sister and Aeroplane mines the tungsten content diminished downward to such an extent that the scheelite present in the deeper parts of the mines is no more than half that contained in the ore mined at the surface. Lemmon [8] reports a similar situation in the Lucky Strike mine. In the Little Sister mine the size of the tactite body, as well as the grade of the ore, decreases downward. Similar relationships may exist in the other Deep Canyon mines, which have not yet been explored to sufficient depths to show the vertical distribution of the metamorphism and mineralization. This relationship suggests that the most intensive additive metamorphism has taken place in the upper part immediately beneath a capping impervious to upward-moving solutions. Such a capping seems most likely to have been the enclosing igneous rock. If so, the metasedimentary blocks are inclusions rather than roof pendants. In this connection it should be noted that the White Caps deposit is overlain by quartz monzonite and that scheelite occurs immediately beneath this capping. The ore body has not been explored to sufficient depth to determine the distribution of the scheelite. Before mining, the deposit at the Tungsten Blue mine was partly covered by hornblende gabbro.

In the mines along the Round Valley pendant entirely different conditions seem to prevail. There, the amount of tactite and the grade of ore seem to increase as the granite contact is approached. No relationship between depth and grade of ore has been shown to exist.

Grade

The scheelite content of all the Tungsten Hills deposits is low, and only the unusual combination of factors that make for cheap mining has permitted their continued exploitation up to the present time. The average grade of ore mined initially in most of the deposits has been about 0.5 percent WO_3, but ore of this grade remains in only a few mines.

Reserves

The reserves of tungsten ore in the mines of the Tungsten Hills are small, probably between 100,000 and 200,000 tons containing 40,000 to 80,000 units of WO_3. In part, the smallness of the reserve figure reflects significant depletion of the total ore that can be expected to be extracted from these deposits. In part, however, it is a result of economic factors that make mining of low-grade tungsten ores profitable only for short periods, usually coinciding with times of national crisis. During these periods when mining is profitable, the ore is mined as cheaply and with as little development as possible.

Outlook for New Discoveries

The Tungsten Hills have been prospected since the discovery of scheelite there 30 years ago; consequently the opportunities for new discoveries are not so good as in the less intensively prospected high Sierra. Nevertheless, the development in the last few years of the White Caps and the Tungsten Blue mines from unencouraging surface showings gives reason to hope that other such showings may be developed into ore bodies. As has been already pointed out, both of these deposits are partly covered by intrusive rock and, before erosion reached its present level, may have been completely covered. Both ore bodies contained significant quantities of tungsten at shallow depths.

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[8] Lemmon, Dwight M., op. cit., p. 510.

From the long-range viewpoint the Tungsten Hills offer a field for exploration for ore in metamorphic rocks that do not crop out at the surface. Such exploration, either by geophysical methods or by wildcat diamond drilling, should be confined to the areas of quartz diorite and hornblende gabbro, where numerous inclusions of metamorphic rock are known to occur, or to the contact between the quartz monzonite and granite, along which metamorphosed remnants of the original wall rock of the quartz monzonite may be found.

MINES

Accompanying this report are maps of the Little Sister, Aeroplane, Jackrabbit, Tungsten Blue, and White Caps mines in the Deep Canyon area, and of the Western, Little Shot, and main part of the Round Valley mines along the northern contact of the Round Valley pendant. As no mining operations have been carried on at the Lucky Strike mine in the Deep Canyon area or in the eastern workings of the Round Valley mine since they were mapped by Lemmon, we have prepared no additional maps of them. Readers interested in these deposits are referred to Lemmon's 1941 report.[9]

Deep Canyon Area

Little Sister Mine. The Little Sister mine is in a block of metamorphic rocks enclosed in quartz diorite (pl. 8). The metamorphic rocks are mainly tactite, but include light-colored calc-silicate rock and coarsely crystalline white marble. The main development is a large glory hole 300 feet long, 80 to 120 feet wide, and about 100 feet deep. Numerous raises connect this glory hole with a haulage adit beneath it. Other workings include a much smaller glory hole southwest of the main glory hole and several small stopes between the bottom of the main glory hole and the adit level.

The Little Sister mine has been the largest producer of tungsten ore in the Tungsten Hills. Approximately 150,000 tons has been mined, practically all in the period 1916-18, when it was operated by the Tungsten Mines Company. Hess and Larsen[10] state that the more than 100,000 tons mined up to the time of their visit in 1918 contained about 0.5 percent WO_3. The El Diablo Mining Company worked the mine from 1937 to the end of 1940 and produced 14,372 units of WO_3 from 24,175 tons of ore. The mine was last operated for a brief period in 1941 by the Bishop Tungsten Company, which, however, was unable to find any commercial ore and stopped operations after mining only 2,900 tons.

The beds are nearly vertical and strike northwest, parallel to the long dimensions of the tactite body and the main glory hole. All the rock types appear to have been derived from limestone by contact metamorphism. Two faults striking northeast and dipping 68° to 70° SE. are exposed in the main glory hole, and a third is intersected by the western branch of the adit level. The ore body at the level of the glory hole is terminated by the southeast fault. This fault has quartz diorite on its hanging wall, a relationship that suggests reverse movement.

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[9] Lemmon, Dwight M., op. cit., pp. 510-513.
[10] Hess, F. L., and Larsen, E. S., op. cit., p. 271.

The tactite decreases in size downward, owing in part to the encroachment of quartz diorite and in part to downward change of the western part of the tactite to light-colored calc-silicate rock. Decrease in tungsten with depth is indicated by the disparity between the amount of scheelite contained in the ore mined from the glory hole and that in the tactite exposed in the adit level.

Several small bodies of tactite occur along the crest of the ridge that extends west from the Little Sister mine. They have been developed by means of small glory holes and short adits. During the 1916-18 period, ore from these bodies was mined by the Tungsten Mines Company in connection with their operation at the Little Sister mine. Very little ore remains in them.

Aeroplane Mine (Mesa Tungsten Mine). The Aeroplane mine is about half a mile southeast of the Little Sister mine on a ridge between Deep Creek and McGee Creek. Most of its production was made during World War I, when it was operated by the Standard Tungsten Company. In 1940, it was operated as the Moonlight mine and in 1942, 1943, and 1944 as the Mesa Tungsten mine, but the production in those years was small. The total production to the end of 1945 amounted to 51,000 tons from which 16,000 units of WO_3 was recovered.

The average grade of all the ore mined was probably between 0.4 and 0.5 percent WO_3. In 1918, the Standard Tungsten Company produced 12,544 units of WO_3 from 44,000 tons of ore, a yield of 0.285 percent WO_3. In April 1944, the yield was not more than 0.2 percent, for only 4 to 5 units was recovered from 25 tons of ore mined daily. The recovery, however, was only about 50 percent, for a composite sample of the tailings contained 0.21 percent WO_3. As in the Little Sister mine, the tactite beneath the old workings contains little scheelite.

The mine is in a small crescent-shaped block of metamorphic rocks that lies between quartz diorite on the north and west and a stock of aplitic granite on the east (pl. 9). Quartz monzonite is in contact with the metamorphic rocks at the two ends of the crescent (pl. 7). Dikes of all the intrusive rocks penetrate the metamorphic rocks.

The metamorphic rocks include coarsely crystalline marble, light-colored calc-silicate rock, hornfels, quartzite, tactite, and meta-igneous dike rocks. Most of the tactite is composed of pale-pink garnet (grossularite) and yellow-green epidote; but near the ore bodies both minerals are darker owing to increase in iron content, and the rock also contains quartz, sphalerite, and scheelite. The marble, calc-silicate rock, and tactite apparently have been formed by the metamorphism of limestone, for they grade into one another along the strike.

Two mineralized zones have been discovered, and one of these has supplied almost all the ore. The main zone consists of two beds, which strike north and dip vertically. The beds are separated by about 20 feet of calc-silicate and meta-igneous rock. The eastern one is developed by means of a glory hole 150 feet long, 30 to 40 feet wide, and at least 100 feet deep. The ore is removed through a haulage level that is connected with the glory hole by raises. Where this bed is exposed in the haulage adit, it contains very little scheelite. The western bed is developed by means of an irregularly enlarged, inclined shaft. The bed is cut off by quartz diorite before reaching the haulage adit.

Another small mineralized zone lies about 300 feet north of the glory hole. This zone is tabular, parallel to beds that strike northeast and dip about 30° SE. It averages 4 feet in thickness and is about 40 feet long. It has been explored by means of an adit that intersects the zone about 80 feet below the outcrop. A raise from this adit joins a small stope that extends along the mineralized beds to the surface. The scheelite content is greater in the stope than in the adit, but it is low in both places. Several prospect pits and short adits explore other showings in the tactite, but no ore bodies have been found.

All the reserves are contained in extensions of the mineralized tactite beds developed by means of the glory hole and the enlarged shaft west of it. The ore probably contains not more than 0.4 percent WO_3, and the average grade of any mineralized block large enough to mine may not exceed 0.3 percent WO_3.

Jackrabbit Mine. The Jackrabbit mine is about 2,500 feet north of the Little Sister mine on the southwest side of a tributary to Deep Canyon. The mine workings include a 200-foot haulage adit and three small glory holes, which are connected with the haulage adit by means of raises (pl. 10). Judging from the size of the glory holes, about 2,000 to 3,000 tons of ore has been taken from the property. Most of this was mined in the 1916-18 period by the Tungsten Mines Company in connection with their operation at the Little Sister mine, but the property was worked briefly by lessees in 1940 and again in 1943-44.

The mine is in a small body of tactite, which is enclosed in hornblende gabbro and quartz diorite. On the surface the tactite body is separated into two parts by a narrow band of epidotized gabbro. Hornblende gabbro surrounds the southern part of the tactite body and is epidotized for an average distance of about 15 feet from the tactite. The northern part of the tactite body is in direct contact with gabbro that has not been epidotized. Only the northern part of the tactite reaches downward to adit level. It is penetrated by numerous dikes of hornblende gabbro and quartz diorite.

Three small ore shoots, all along steeply dipping beds, have been mined by means of the glory holes. These shoots average about 4 feet in thickness, and each extends 20 to 40 feet along the strike. The ore in them contains an estimated 0.2 to 0.7 percent WO_3.

Tungsten Blue Mine. The Tungsten Blue mine, owned by Mr. Nick Pappas of Bishop, has been the most productive deposit developed recently in the Tungsten Hills. The mine is about 3,700 feet east of north from the Little Sister mine and about 1,000 feet northeast of the Jackrabbit mine. The workings consist of a glory hole, underground stopes, a 300-foot haulage adit, a grizzly level beneath the main glory hole, and an upper adit that lies mainly in the northeast wall of the glory hole. A raise connects the haulage level with the glory hole and stopes.

The total production to the end of 1945 was 38,400 tons, from which 10,460 units was recovered, a yield of 0.273 percent. In 1940 and 1941, the Bishop Tungsten Company mined about 35,000 tons, and in 1943 and 1944 the El Diablo Mining Company produced the small additional tonnage. Examination of the tactite under ultraviolet light shows that scheelite is disseminated throughout the tactite, but that it is more abundant along fractures.

The ore body consists entirely of tactite, which is enclosed in hornblende gabbro. Adjacent to the tactite the hornblende gabbro is epidotized in many places; farther away the epidotization is confined to fractures. At several places the contact between epidotized gabbro and tactite is gradational and some of the tactite along such contacts has been formed from gabbro rather than from a calcareous sediment.

The extent of the tungsten deposit seems to be fairly well established. The south, west, and west part of the north sides are vertical where they are exposed in the main glory hole; but exposures in the grizzly level beneath the main glory hole and in the upper adit indicate that hornblende gabbro dips from the northeast under the deposit. The shape of the ore body is shown in the sections (pl. 11).

Tungsten Peak Prospect. The Tungsten Peak prospect, owned by Nick Pappas, is about half a mile north of the Tungsten Blue mine. It is at the southern tip of the fairly extensive block of metamorphic rocks that extends southeast into the quartz monzonite from the contact between granite and quartz monzonite.

The prospect consists of a small block of tactite entirely surrounded by quartz monzonite. On the northwest side it is separated only a few feet from the main metamorphic block. The tactite has been explored by means of a shallow shaft. The tactite found so far does not contain sufficient scheelite to be of commercial grade as indicated under ultraviolet light.

White Caps Mine. The White Caps mine is dug into the west bank of McGee Creek, about 2,000 feet south of the Aeroplane mine. The mine development consists essentially of a stope, 100 feet long, 25 feet high, and from 5 to 20 feet wide. This stope extends from an adit level to a shaft level whose floor was only 16½ feet beneath that of the adit level. Maps of the two levels before stoping are shown in Figure 2.

The original location was made in 1940 by E. C. Castle and "Cap" Aubrey of Bishop, on a small, nearly barren outcrop of tactite entirely surrounded quartz monzonite. Exploration on the adit level indicated that this unpromising showing was part of a much larger body of tactite buried beneath quartz monzonite and that it contained an ore shoot. The tactite body has been shown to extend more than a hundred feet beneath quartz monzonite in a westerly direction from the outcrop. Several raises in the roof of the stope pass into quartz monzonite within a few feet. The width of the tactite is at least 20 feet; the bottom has not been reached. The floor of the stope is at the water table, below which mining costs would have been increased substantially. The bedding faintly visible in the tactite is vertical and strikes parallel to the stope and to the longer horizontal dimension of the tactite body.

A single ore shoot, 80 feet long and averaging 10 feet wide, has been developed. Thirty feet from the mine portal the shoot is 20 feet thick and under ultraviolet light appears to contain about 1 percent of WO_3. The thickness and grade decrease westward to the face of the stope, where the tactite contains almost no scheelite. Approximately 2,500 tons of ore mined from the stope in 1943 and 1944 by Aaron J. Smith, operator of a custom mill near Bishop, is reported to have averaged 0.45 percent WO_3.

All the reserves are contained in the downward extension of the known ore shoot, but lack of any exploration beneath the stope makes it impossible to predict the depth to which the ore may extend.

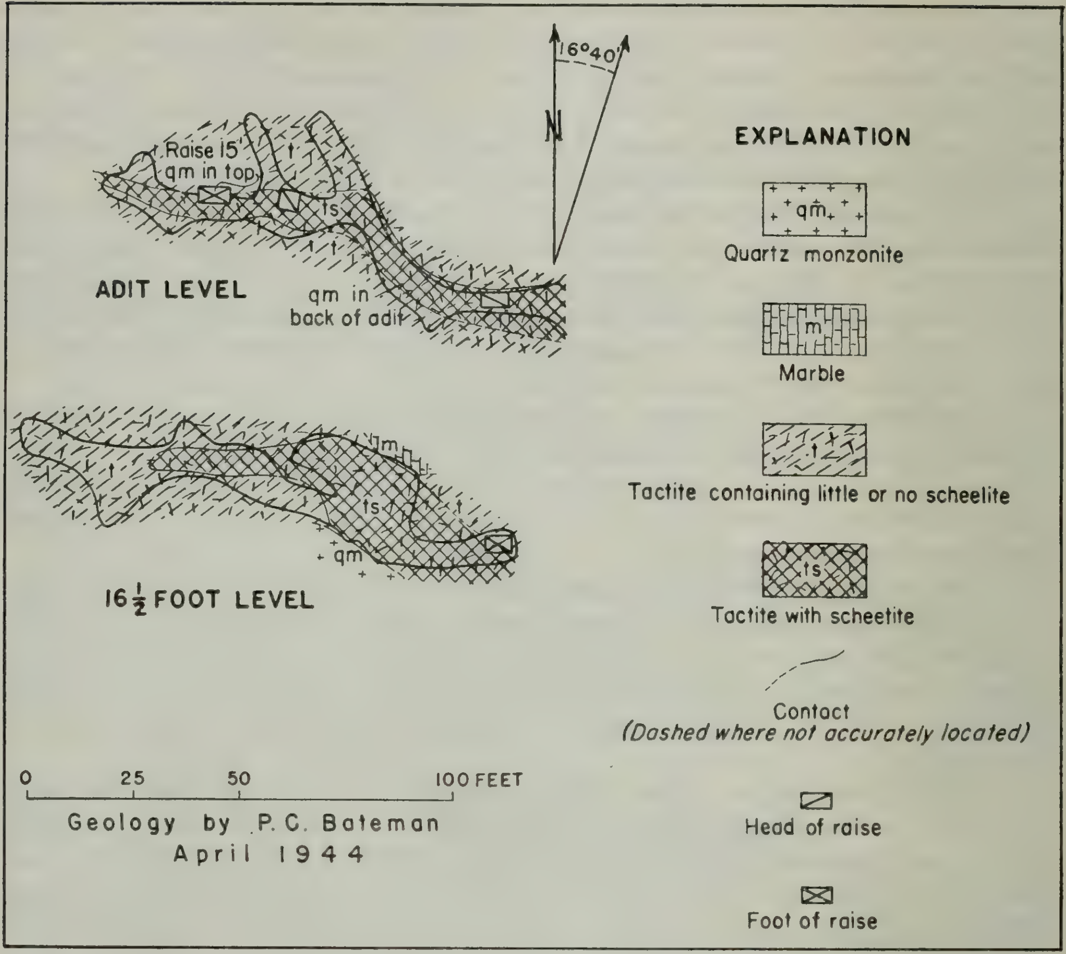
16°40'
N
Raise 15' qm in top
ts
t
ADIT LEVEL
qm in back of adit
m
ts
t
qm
16½ FOOT LEVEL
0
25
50
100 FEET
Geology by P. C. Bateman
April 1944
EXPLANATION
qm
Quartz monzonite
m
Marble
t
Tactite containing little or no scheelite
ts
Tactite with scheetite
Contact
(Dashed where not accurately located)
Head of raise
Foot of raise

FIGURE 2. Geologic maps of the underground workings of the White Caps mine.

Lookout Prospect (Tiptop Claims). A fairly extensive body of tactite caps the hill 1,500 feet northeast of the Aeroplane mine. Although several prospect pits and short adits have been dug into it, no ore bodies have been found. Near the contact with the intrusive rocks the tactite contains scheelite in amounts that, according to Lemmon,[11] might average 0.1 percent WO_3.

Hilltop Prospect. The Hilltop prospect is on the northeast side of the ridge that projects southeast from the eastern edge of the Tungsten Hills. The deposit consists of two bodies of tactite enclosed in hornblende gabbro. The northern one is developed by means of a glory hole with a haulage adit beneath, the southern by means of a short adit and surface trenches. In 1943, tactite from the glory hole was hauled to the custom mill operated by Aaron J. Smith, but the scheelite content proved to be too low for profitable operation. Both tactite bodies decrease in size downward.

Van Loon Prospects. H. A. Van Loon of Bishop has prospected two localities in the western part of the Tungsten Hills. Although these deposits are not in the Deep Canyon area, for convenience they are grouped here with the Deep Canyon deposits. One of them, the Raindrop prospect, is similar in occurrence to the Deep Creek deposits, but in the other scheelite is contained in a quartz mass.

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[11] Lemmon, Dwight M., op. cit., p. 509.

The Raindrop prospect consists of a small elongate body of metamorphic rocks enclosed in quartz monzonite. The main part of the body is tactite, but the two ends are light-colored calc-silicate rock. The tactite is 30 feet long and 6 to 16 feet wide. The longer dimension trends N. 80° W., parallel to the strike of the bedding. Both bedding and walls are vertical. The tactite has been explored 15 to 20 feet from the surface in an open cut. Scheelite is distributed irregularly through the tactite. The average content of WO_3 is probably less than 0.5 percent, although locally bunches of ore are higher grade.

The other Van Loon prospect consists of a more or less circular body of quartz enclosed in quartz monzonite. Scheelite occurred locally in the quartz but has been mined out. The quartz body has been explored through a short adit and a raise. The quartz is bordered by altered quartz monzonite. Although other occurrences of quartz as dikes and irregular masses associated with altered quartz monzonite are fairly abundant in the Tungsten Hills (pl. 7), no other body of quartz is known to contain scheelite.

Round Valley Area

Round Valley (Big Shot) Mine. The Round Valley mine is the oldest and has been the most productive mine in the Round Valley pendant. Although most of the production was made in 1917 and 1918, it has been operated by several companies intermittently since 1928. To the end of 1945, 19,000 units of WO_3 was recovered. In 1918, the only year for which complete production figures are available, 9,500 units of WO_3 was recovered from 32,000 tons of ore mined, a yield of 0.3 percent WO_3; but the tailings contained close to 0.2 percent WO_3. The mill heads probably averaged about 0.5 percent WO_3.

The deposit is in the northeast part of the Tungsten Hills along the north side of the Round Valley pendant, where it is in contact with granite. In the vicinity of the mine the pendant is composed almost entirely of marble, and of tactite and light-colored calc-silicate rock that were derived from the marble. Within the contact zone tactite predominates near the granite, and calc-silicate rock predominates near the marble; but commonly they occur together in thin, alternating layers parallel to the bedding. For this reason, all the silicated calcareous rocks are represented as a single unit on the maps and sections.

The beds are somewhat contorted but in general strike north and dip west, intersecting the contact at a wide angle. The contact between the pendant and granite in the vicinity of the mine dips south about 50°. Many fractures are evident along the contact. The mine is divided into two parts. Plate 12 shows the western part, which contains the productive ore bodies. No mine work has been done in the eastern part, from which only a small amount of ore has been mined since Lemmon's [12] examination. Workings that develop the western part include a large glory hole, several prospect pits and small glory holes, two adit levels, a 78-foot inclined shaft, and a level from the bottom of the shaft.

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[12] Lemmon, Dwight M., op. cit., pp. 512-513.

The silicated zone is 150 feet wide at the west end of the surface area mapped, and narrows to only a few feet at the east end. Some beds are replaced by silicated rock farther from the granite than others, and the contact between the marble and silicated rock is therefore irregular.

Although scheelite occurs along the granite contact, the principal ore zones are parallel to the bedding. The scheelite on the granite contact is too irregularly distributed for mining, although pits have been dug on some of the better showings. In the bedded zones the amount of scheelite diminishes with distance from the granite, and nowhere does the tungsten mineralization continue beyond the silicated zone into the marble.

In the main glory hole and in the small pits to the west along the granite contact, the silicated rock within 20 feet of the granite is limonite-stained, especially along fractures. These stains are the result of the weathering of pyrite in small quartz stringers in the tactite. The quartz stringers contain no scheelite, but do contain epidote and manganese oxide minerals.

Several bedded ore zones have been explored. The main zone, which has supplied most of the ore mined is about 20 feet thick and mineralized as much as 100 feet from the granite contact. It is developed by means of the large glory hole, the inclined shaft level, and numerous raises and small stopes between the glory hole and the inclined shaft level. The upper part of this ore zone is mined out. No ore remains in the walls of the glory hole, and only a little is left between the glory hole and the inclined shaft level. The gopher-hole type of stopes above the shaft level makes it almost impossible to calculate the tonnage remaining. The ore zone is unexplored beneath the inclined shaft level. Some of the ore appears under ultraviolet light to contain as much as 1 percent WO_3, but the scheelite is not evenly distributed and the average is probably about 0.5 percent WO_3. The exposures of the mineralized zone on the inclined-shaft level contain less than this amount, but the low grade may be a local condition.

A mineralized zone east of the main zone is explored by means of the adit east of the large glory hole, the easternmost glory hole in the area mapped, and the glory-hole level. It is mineralized across a width of about 20 feet, but appears to contain only 0.2 to 0.3 percent WO_3, considerably less than the ore mined from the main ore zone. The distribution of scheelite is irregular. Narrow streaks of good-grade ore are localized along seams parallel to the bedding and along crosscutting fractures.

Several other weakly mineralized bedded zones are explored by the inclined-shaft level and surface pits. The most extensive and strongly mineralized of these is the one explored by the winze at the west end of the inclined-shaft level. It appears under ultraviolet light to contain not more than 0.5 percent WO_3 across a thickness of about 6 feet.

The best opportunity for finding additional ore seems to be through exploration of the known ore zones at depth, especially of the downward extension of the main ore zone below the shaft level and of the zone exposed in the winze at the west end of the shaft level.

Western Tungsten Mine. The Western Tungsten mine is 2,000 feet west of the Round Valley mine, at the western end of the Round Valley pendant. It is the property of J. F. Birchim and Bert Shively. In 1937-38 it was operated by the Pacific Tungsten Company, in 1940 by the Western Tungsten Company, and in 1943 by the Tungsten Reduction Company.

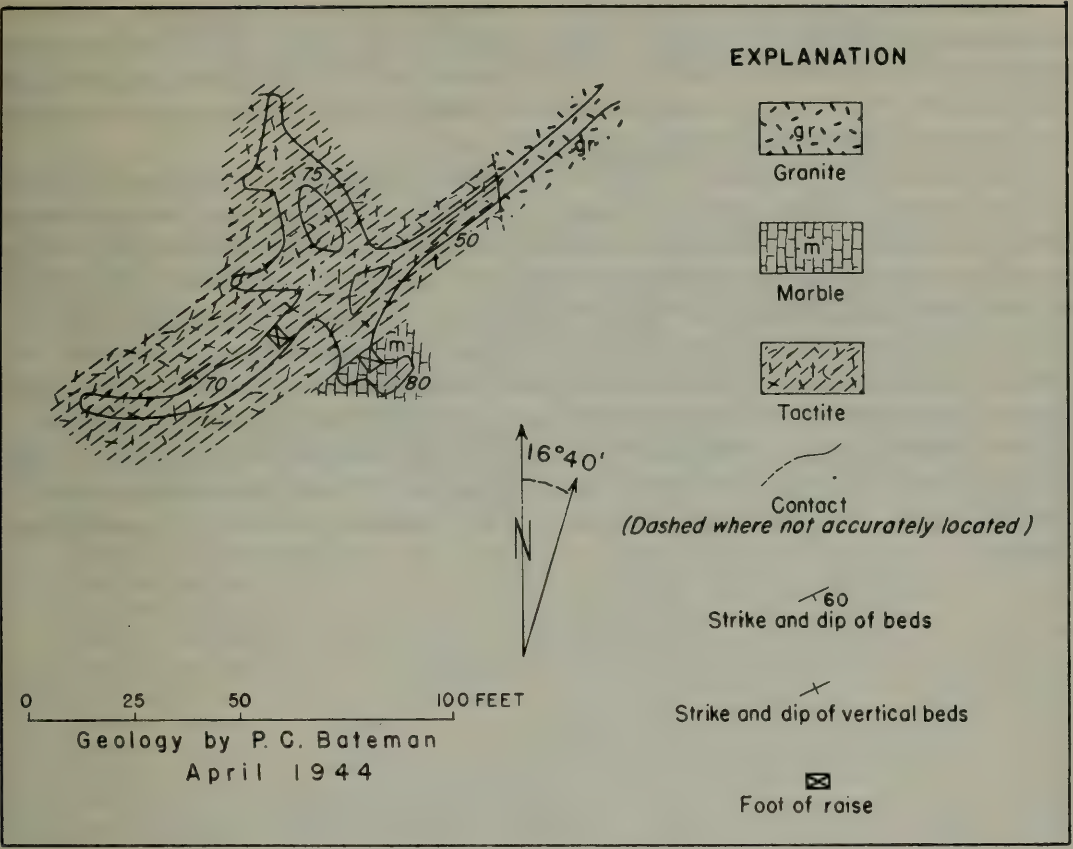
EXPLANATION
gr
Granite
m
Marble
Tactite
Contact
(Dashed where not accurately located)
60
Strike and dip of beds
Strike and dip of vertical beds
Foot of raise
75
50
gr
m
70
80
16°40'
N
0
25
50
100 FEET
Geology by P. C. Bateman
April 1944

FIGURE 3. Geologic map of the underground workings of the Little Shot mine.

The mine workings include two open cuts, several prospect pits and trenches, a small glory hole used primarily for a transfer chute, and a haulage adit (pl. 13). The mill was dismantled in 1944. The total production, judging from the amount of ore removed from the mine workings, has amounted to about 10,000 tons of ore reported to have contained 0.4 to 0.5 percent WO_3.

In the vicinity of the deposit the pendant is composed of several nearly vertical, elongate bodies of tactite interstratified with schist and hornfels. It is not clear whether the tactite bodies are parts of a single, isoclinally folded and cross-faulted bed, or whether several beds are represented. The curved ends of some of the bodies suggest that they are terminated by northwest-striking premineral faults. The contact between the metamorphic rocks and granite, between the adit level and the surface exposure of the contact, dips 30° SW., truncating the structures in the metamorphic rocks.

The abundance of dark minerals in the tactite decreases gradually with distance from the granite, and the most distant parts contain many light-colored silicate minerals. Scheelite occurs in ore shoots within the tactite bodies. The two shoots that have been explored are both near the granite contact. The eastern shoot is developed by means of the adit and larger open cut, the western by means of the smaller open cut. Little scheelite occurs in the surface exposures of tactite away from the known ore shoots, but these parts of the tactite are probably all at greater distances from the granite than the parts bearing tungsten. Exploration of the deeper parts of the tactite bodies where they are nearer granite might result in finding other ore shoots.

The shoots end abruptly, often along premineral fractures, with no apparent gradation of values. Under ultraviolet light, parts of the open cuts fluoresce brilliantly owing to the presence of many large paper-thin scheelite crystals along fractures in the tactite. Equidimensional crystals are sparsely disseminated through the rock.

Little Shot Prospect.—The Little Shot prospect is near the east end of the Round Valley pendant, about 1,500 feet east of and several hundred feet higher than the Round Valley mine. The mine workings include an adit, comprising about 250 feet of level workings; a 25-foot shaft that connects the adit level with the surface; and several prospect pits (fig. 3). The workings are in a small body of tactite, bounded on the west by quartzite (pl. 7) and on the north and northeast by granite. The relations of the tactite to the quartzite are not clear, but pre-intrusive faulting or folding seems necessary to explain the anomalous position of the tactite. Under ultraviolet light the tactite can be seen to contain evenly disseminated, fine-grained scheelite. The ore is probably of marginal grade.

GEOLOGY OF THE PLACERITA OIL FIELD LOS ANGELES COUNTY, CALIFORNIA *

By Gordon B. Oakeshott **

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* Development in this field has been very rapid during the early part of 1949; information used as a basis for this report is not later than June 1, 1949.

** Associate Geologist, California State Division of Mines. Manuscript submitted for publication July 21, 1949.

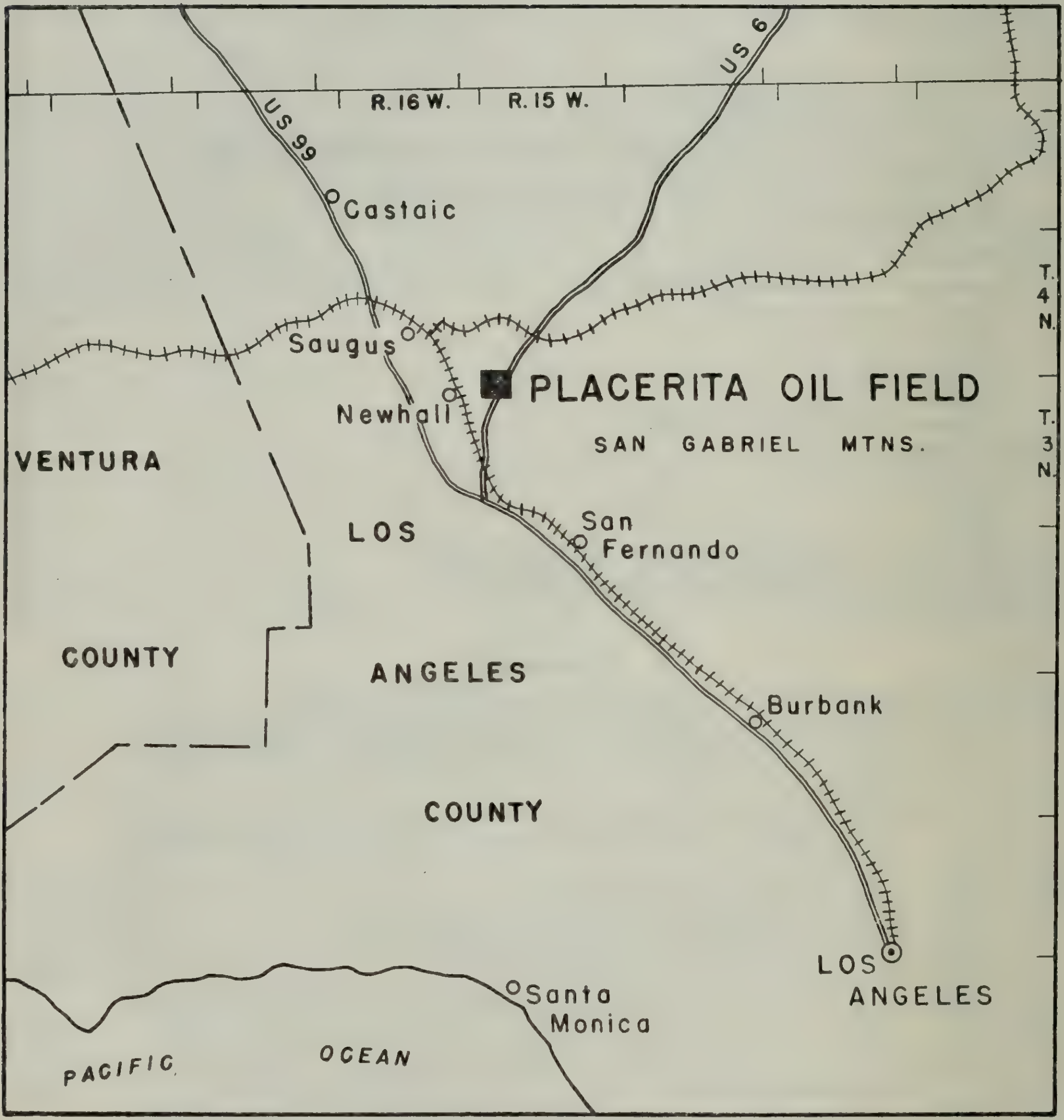
R. 16 W.
R. 15 W.
US 99
US 6
Castaic
Saugus
Newhall
PLACERITA OIL FIELD
SAN GABRIEL MTNS.
T. 4 N.
T. 3 N.
VENTURA
COUNTY
LOS
ANGELES
COUNTY
San Fernando
Burbank
LOS ANGELES
Santa Monica
PACIFIC
OCEAN

FIGURE 1. Index map showing location of Placerita Oil Field, Los Angeles County, California.

ABSTRACT

Nelson-Phillips Oil Company has been credited with a new field discovery in Placerita Canyon at Sierra Highway (U.S. 6) approximately 2 miles east of Newhall in western Los Angeles County, as a result of successful completion of their well Kraft 1 in the SE¼ sec. 31, T. 4 N., R. 15 W., S.B., in April, 1948. By the end of 1948, 20 wells were completed from locations on both sides of the highway; active development had increased that number to 68 producing wells by early June 1949. Actually, since 1920, a very small production has come from the same structure and horizon in the area less than 1 mile southwest of the new discovery well. The new wells in the discovery area are each producing from a few barrels to more than 100 barrels per day of 11° to 16° gravity oil from depths of 600 to 1600 feet. In January 1949, Ramon Somavia initiated a new development in a northward extension of the field, by bringing in well Juanita 1, a mile north of the Nelson-Phillips well. Wells in the north extension are averaging 550 barrels a day of 22° gravity clean oil from depths of 1300 to 2100 feet.

Geology of the area is complex but consists essentially of Tertiary sediments dipping northwestward off the very much older crystalline rocks of the basement complex which are exposed in the western San Gabriel Mountains as close as 1 mile to the southeast of the producing wells. The area is at the eastern end of the Cenozoic Ventura basin. Formations exposed, in the area mapped, include upper Miocene Mint Canyon, the Elsmere and Repetto siltstone members of the lower Pliocene Repetto formation, middle Pliocene lower Pico beds, marine beds of the upper Pliocene upper Pico member of the Pico formation, continental beds of upper Pliocene age, herein named the "Sunshine Ranch" member of the Pico formation, the lower Pleistocene Saugus formation, two stages of upper Pleistocene terrace gravels, and Recent alluvium.

The northwest-trending San Gabriel fault, with its branches, dominates local structure. A number of minor asymmetrical anticlines and synclines roughly parallel the fault and strike at low angles into it. Both folding and faulting had begun at least as early as upper Miocene time and continued into Recent time, but the major periods of such activity were post-Mint Canyon-pre-Elsmere, and post-Saugus-pre-older Terrace.

Wells producing June 1, 1949 were distributed in two principal groups: one, along or near the principal northeast-trending axis of the Placerita anticline and north to the middle of sec. 31, T. 4 N., R. 15 W., S.B.; a second, around the center of the north boundary line of sec. 31. In the first, oil production is coming from some 200 feet, more or less (including barren zones in between oil sands), of coarse to fine oil sands, of the Sunshine Ranch and upper Pico members of the upper Pliocene Pico formation; average production per well is 47 barrels per day of 11° to 16° gravity oil. Production in the north extension of the field is from the upper Pico formation also, but some of the wells are flowing and average 550 barrels per day of 21° to 23° gravity clean oil. About 430 acres were proven by June 1, 1949, and rather definite boundaries of the field were established.

Major structural features conditioning the accumulation of the oil are the westward-plunging Placerita nose and the San Gabriel fault and folds associated with it. Stratigraphically, up-dip lensing, crossbedding, and minor unconformities assisted in the formation of traps for oil. Source rocks may be found in nearby organic shales of Eocene, Miocene, and Pliocene ages.

Successful wells in this region appear extremely unlikely north of the San Gabriel fault zone where the continental upper Miocene Mint Canyon formation is widely exposed, and unlikely east of a north-south line marked by the Whitney fault. Some production may be obtained farther down dip to the west and southwest, but some recent dry holes in those areas minimize this prospect.

Successful development of this small shallow oil field directs attention to the fact that any semblance of favorable structure involving marine Tertiary beds dipping off basement rocks in southern California is worth exploration by shallow wells drilled to the basement.

ACKNOWLEDGMENTS

The writer is indebted to Dr. H. R. Gale for assistance in identifying Pliocene fossils; to Dr. John C. Hazzard for the results of his work on the Sunshine Ranch formation, and to the Union Oil Company for release of the latter. Dr. W. S. W. Kew and the Standard Oil Company furnished

data on the Standard Placerita fee wells, and Mr. H. D. Hobson furnished data on General Petroleum Corporation's well Castruccio No. 1. Dr. G. D. Hanna and Dr. Leo Hertlein made some helpful observations on the fossils and Dr. Richard Jahns was helpful in discussion of eastern Ventura basin problems. The State Division of Oil and Gas furnished a map showing well locations and also some data on dates of well completions and abandonment.

INTRODUCTION

Location

The new Placerita oil field extends from Placerita Canyon, at Sierra Highway, about a mile north and a mile west, 2 miles due east of Newhall in western Los Angeles County, at the western end of the San Gabriel Mountain range. The 68 producing wells, plus the 22 being drilled on June 1, 1949, are located in sec. 31, T. 4 N., R. 15 W., S.B., and adjacent borders of the sections north, south, and west. The field is approximately 1 mile north of the old Whitney Canyon area, abandoned since 1937; 1½ miles north of Elsmere area, which still has a few small wells pumping; and 2½ miles due west of the old Placerita Canyon schist area which produced a little high-gravity oil from basement rocks several years ago. A number of the wells are located on the flat floor of Placerita Canyon, others are on the adjacent low hills. Both the Placerita Canyon Road and Sierra Highway are paved and offer easy access to the field.

Purpose and Scope of Study

The Placerita field is in a part of Los Angeles County of considerable interest to petroleum producers; the shallow depth of oil sands, low cost of wells, and ease of transportation are attractive to both small and large operators. Principal interest in the region, however, attaches to the fact that commercial production is being obtained from a poorly defined, faulted structural nose, with the producing sands exposed nearby, and dipping off basement schists and granitic rocks which are exposed a mile from the field. The occurrence emphasizes possibilities in other similar situations.

Over a period of years the writer has been mapping the San Fernando quadrangle on 1:24000-scale topographic sheets and on photographs of the same scale. Field work has progressed from the east, so that the approach to the Placerita area has been from east to west in those portions of the Ventura and Los Angeles basins that are included in that quadrangle. Although much geological work has been done in the region, comparatively little of it has been published. Conclusions in the report are based mainly on surface geology, as the writer has had only limited access to well data.

Previous Geologic Work

It is not appropriate to the purpose of this report to review all published work bearing on the general area discussed, but mention will be made of the principal published accounts directly referring to some part of the area shown on the accompanying geologic map.

Basic geology of the region was worked by Kew[1] whose paper on the geology and oil resources included a geologic map on the scale

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[1] Kew, W. S. W., Geology and oil resources of part of Los Angeles and Ventura Counties, California: U. S. Geol. Survey Bull. 753, 197 pp., 1924.

1 : 62500. Later he was co-author with Brown [2] of a paper dealing with the occurrence of oil in basement rocks in the old Placerita schist area, just 2½ miles due east, or upstream from the discovery well in the new Placerita field. The report is accompanied by a geologic map on a scale of approximately 1 : 24000, which extends into the eastern border of the geologic map of the present report. Kew [3] was also author of a paper on the Newhall oil field, including a brief discussion of the Elsmere Canyon, Whitney Canyon, and Placerita Canyon areas as known in 1942. Miller [4] published a paper and geologic map of the western San Gabriel Mountains but did not differentiate the Tertiary sedimentary rocks. Grant and Gale [5] made significant contributions to the stratigraphy and paleontology of the marine Pliocene of the region. Jahns' [6] study of the stratigraphic problems of the eastern Ventura basin has important bearing on the geology of the area mapped north of the San Gabriel fault, but his published map on a scale of approximately 1 :62500 did not extend quite as far south as the area mapped for this paper. The history of oil developments of the Elsmere-Whitney-Placerita areas, up to 1934, was covered by Walling.[7]

HISTORY OF OIL PRODUCTION IN THE PLACERITA AREA

Development Prior to 1948 [8]

The first well drilled within the limits of the Placerita oil field (pl. 15) was Equity Oil Company, Daisy 1, completed in 1920 at a depth of 975 feet. It produced a little very heavy oil. The well has since been known as "Nile 1" and "York 1," and is now the Guiberson Oil Company York 1. It was deepened in 1921 to 1394 feet, and late in 1925 produced an average of 6 barrels per day of 14° gravity oil, used for fuel. Altogether, four wells were drilled between 1920 and 1933; maximum depth was 1563 feet, and production was 6 to 19 barrels per day. Walling [9] says "The wells are drilled into and secure their production from the cross-bedded, poorly assorted sediments of the Saugus formation. Water sands are found in immediate contact with the oil sands and their identification and exclusion has been difficult." Apparently the water difficulties, in addition to low gravity oil and small production, were major factors in the failure to develop the field until rediscovery in 1948. The four wells, shown as Guiberson Oil Company York 1, 2, 3, and 4 on plate 15, were producing an average of 8.9 barrels per day of 11.8° oil and 18.8 percent water, in April 1935. York 1, 2, and 3 are very close to the prolonged axis of the Placerita anticline, and York 4 is about 1000 feet down the flank to the northwest.

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[2] Brown, Arthur B., and Kew, W. S. W., Occurrence of oil in metamorphic rocks of the San Gabriel Mountains, Los Angeles County, California: Am. Assoc. Petroleum Geologists Bull., vol. 16, pp. 777-785, 1932.

[3] Kew, W. S. W., Newhall oil field: California Div. Mines Bull. 118, pp. 412-416, 1943.

[4] Miller, W. J., Geology of the western San Gabriel Mountains of California: Univ. California Los Angeles, Pub. Math., Phys. Sci., vol. 1, no. 1, 114 pp., 1934.

[5] Grant, U. S. IV, and Gale, H. R., Catalogue of the marine Pliocene and Pleistocene mollusca of California: San Diego Soc. Nat. History Mem., vol. 1, 1036 pp., 1931.

[6] Jahns, Richard H., Stratigraphy of the easternmost Ventura basin, California, with a description of a new lower Miocene mammalian fauna from the Tick Canyon formation: Carnegie Inst. Washington Pub. 514, pp. 145-194, June 1940.

[7] Walling, Rolla W., Report on Newhall oil field: Summary of operations, California oil fields, State Div. Oil and Gas, vol. 20, no. 2, pp. 50-58, 1934.

[8] Walling, R. W., op. cit., Elsmere area, pp. 38-43, Whitney Canyon area, pp. 43-46, Placerita Canyon area, pp. 46-50.

[9] Op. cit.

The Elsmere Canyon field, 1½ miles south-southwest of Placerita Canyon, discovered in 1889 by Pacific Coast Oil Company (later Standard Oil), is on a separate structure. Thirty-three wells were drilled in the field. Six were producing in 1942. They were less than 840 feet deep, averaged 2 barrels per day of 14° to 16° oil, and 75 percent water; a few were still pumping in June 1949. Kew [10] says of the field: ''Oil has accumulated in west-dipping beds against a fault which trends in a northwesterly direction along Elsmere Canyon. No production has been found north of the fault. The rocks exposed at the surface are a part of the Pico formation, probably the lower part, and rest unconformably upon rocks of middle Eocene age.'' Numerous tar seeps and extensive exposures of tar sands in Whitney Canyon, Elsmere Canyon and vicinity encouraged early exploration for oil in these areas.

The Whitney Canyon [11] field has been developed by small companies since 1893 but all wells were idle or abandoned by 1937. The wells were less than 1,500 feet deep and produced less than 25 barrels per day of 14° oil from Pliocene beds and 30° oil from the underlying Eocene. Kew [12] indicates ''The oil here was accumulated on a northwestward-dipping series of Saugus beds (uppermost Pliocene and Pleistocene) and a thin section of Pico formation (Pliocene) overlying unconformably the middle Eocene. In the Whitney Canyon area a north-trending fault lies a short distance east of the wells.'' Kew believes it ''possible that the oil has migrated into the Pliocene beds from the underlying Eocene, or lenticularity of the beds has been the controlling factor.'' Oil was produced from all three formations.

A very small amount of light oil was produced from the basement rocks in upper Placerita Canyon 2½ miles east of the new Placerita field, an occurrence discussed by Brown and Kew.[13] For a time, the wells averaged about a barrel per day of 26° to 38° gravity white oil. Brown and Kew believed that the oil migrated from Eocene strata underlying the Saugus in the San Gabriel fault zone, into the crystalline rocks. Their geologic map, on a scale of 1:24000, is just east of the geologic map included with the present report. The crystalline rock exposed in the vicinity of the wells and immediately south of the Placerita fault consists of Rubio diorite gneiss and fragments of the Placerita metasedimentary series. The wells have not produced for many years.

Discovery and Development in 1948 and Early 1949

In late April of 1948 Nelson-Phillips Oil Company brought in Kraft 1 in Placerita Canyon near the south central boundary of sec. 31, T. 4 N., R. 15 W., S.B., initiating development of a ''new'' field. The well is approximately 4000 feet northeast of York 1 and higher on the same structure. It came in flowing an estimated 70 to 100 barrels per day, later settling down to pump 60 barrels a day of 15.6° oil. The well was drilled by Shamrock Drilling Company to a total depth of 2242 feet and plugged back to 717 feet; about 130 feet of oil sand was opened to production; 7-inch casing was perforated between 580 and 717 feet. In June, Kraft 2, 400 feet southwest of the discovery well, was successfully brought in by the company, flowing 80 barrels a day of 16.0° oil, water cut 1 percent, from a total depth of 782 feet. Nelson-Phillips Swall-Ferrier 1, 600 feet due east of Kraft 1, was abandoned, in the same month, as a dry hole after producing salt water only from a total depth of 502 feet. Swall-Ferrier 2 and 3 were also abandoned.

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[10] Kew, W. S. W., Newhall oil field: California Div. Mines Bull. 118, p. 415, 1943.

[11] Kew, W. S. W., op. cit., p. 415.

[12] Op. cit., p. 415.

[13] Brown, Arthur B., and Kew, W. S. W., Occurrence of oil in metamorphic rocks of San Gabriel Mountains, Los Angeles County, California: Am. Assoc. Petroleum Geologists Bull., vol. 16, pp. 777-785, 1932.

Crawford and Hiles Oil Company brought in their first successful well in the field, Newhall 1, in July 1948, for 15 barrels per day of 8.8° gravity oil; total depth of the well was 946 feet.

Standard Oil Company became a producer in the new field when Placerita 1 was brought in during July 1948 for 21 barrels per day of 12.9° gravity oil; total depth was 820 feet. Late in December, Standard had completed six small wells; Placerita 6 produced 24 barrels per day of 15.5° gravity oil; its total depth was 650 feet.

Parbe Oil Company entered production in August with completion of its Philbert Community 3-1, which pumped an estimated 57 barrels per day; its total depth was 1205 feet. Indian Oil Company Wanda Kraft 1 and 2 and Placerita 1 were successfull shallow wells.

By the end of 1948 there were 20 shallow wells producing an average of approximately 40 barrels per day of 11° to 16° gravity oil. Production extended about half a mile on each side of Sierra Highway. The wells were roughly grouped along the flexure on the Placerita nose, here called the Placerita anticline.

In January 1949 Ramon Somavia brought in Juanita 1 flowing 340 barrels per day of 22.4° gravity oil cutting 3 percent water. Bottom of the producing zone is at 1830 feet. Location of the well is near the north border of sec. 31, T. 4 N., R. 15 W., S.B., approximately a mile north of Nelson-Phillips Kraft 1. Additional wells in the vicinity were drilled in rapid succession by Somavia, Rothschild Oil Company, Gordon Oil Company, Trical Oil Company, and Independent Exploration Company. Independent Exploration Company's Newhall Royal Community 1 was completed in early June 1949 for 725 barrels per day of 23° gravity oil, producing from about 100 feet of oil sand; its total depth was 2037 feet. This well, in sec. 30, T. 4 N., R. 15 W., S.B., just north of the south border of that section and a few hundred feet south of the San Gabriel fault, represents the most northerly production in the field to the early part of June 1949. Ten wells in this north extension of the Placerita field were averaging 550 barrels per day of 22° gravity clean oil from depths of 1300 to 2100 feet at that time.

Production in the original southern portion of the field was from 58 wells averaging 47 barrels a day of 14° gravity oil from depths of 600 to 1600 feet.

The northern and southern sections were separated by 1000 feet of untested land.

On June 1, 1949, the Placerita field had 68 producing wells, 22 wells drilling, and 23 abandoned as dry holes. There were 14 operators of producing wells and an estimated 430 acres had been proven.

Table 1. *Summary of exposed rock formations.*

Age		Formation or member	Description	Maximum thickness in area mapped (feet)	Economic interest
Recent		Alluvium	Stream sands and gravels of Placerita Canyon and Santa Clara River.	100+	Water supply. Gold in Placerita Canyon.
		Unconformity			
Upper Pleistocene		Later terrace deposits	Elevated, but unfolded, older alluvium, terrace gravels, and fanglomerate.	175+	Gold in Placerita Canyon.
		Older terrace deposits	Similar to later terrace, but affected by folding and faulting.	500	None recognized.
		Major unconformity			
Lower Pleistocene		Saugus formation	Continental sands and gravels; little consolidated; usually light colors of gray, white, or buff.	2000±	Basal beds may contain petroleum.
		Local unconformity			
Upper Pliocene		Sunshine Ranch member	Continental and brackish water conglomerate, greenish sandstone and mudstone; thin fresh-water limestone beds; red beds.	1300	Basal beds include oil sands of Placerita field.
	Pico formation	Local unconformity			
		Upper Pico member	Marine coarse to fine sandstone; fossiliferous uppermost Pliocene (probably Santa Barbara zone).	1000	Upper beds include oil sands of Placerita field.
Middle Pliocene		Lower Pico member	Marine sandstone and conglomerate; massive fine sandstone and siltstone; fossiliferous calcareous sandstone beds (San Diego fauna).	700	Oil sand in many outcrops; oil seeps.

		Unconformity			
Lower Pliocene	Repetto formation	Repetto siltstone member	Marine brown and gray siltstone and fine sandstone; some brown conglomerate.	300	Some oil sand and seeps in exposures.
		Elsmere member	Marine fossiliferous coarse sandstone and conglomerate; interbedded fine sandstone. Only the continental N.E. extension of these beds in the area mapped.	100+	Much oil sand and many seeps south of area mapped.
	Major unconformity				
Upper Miocene	Mint Canyon		Continental coarse gray and buff sandstone and conglomerate; brown and greenish sandstone; greenish mudstone, thin red sandstone and claystone; white tuff beds; lake beds common.	2400+	None recognized.
	Unconformity?				
Eocene	Domengine and Martinez (?)		Well-indurated shale, sandstone, conglomerate	?	Reservoir for light oil in nearby fields; may have been important source rock.
	Major unconformity				
Pre-Tertiary	Granitic rocks; Rubio diorite gneiss; Placerita series.		Irregular remnants of Placerita crystalline limestone and other metasedimentary rocks (Paleozoic?) intruded by Rubio diorite gneiss (late Paleozoic?) and both intruded by granitic rocks (upper Jurassic?).	?	Reservoir rock for a little light oil in Placerita schist area. Some Placerita crystalline limestone has been quarried in the Little Tujunga quadrangle adjoining the Sylmar quadrangle on the east. Large quantities of Upper Jurassic (?) granodiorite for dam construction quarried in the same quadrangle.

STRATIGRAPHY

Basement Rocks

A series of metamorphic and intrusive granitic rocks of pre-Tertiary age is widely exposed throughout the western San Gabriel Mountains and crops out within a mile of the southeast border of the new oil field. The oldest group is the Placerita series, consisting of scattered remnants of once-extensive and thick limestone, dolomite, shale, and sandstone, metamorphosed to marble, schist, and quartzite. The Placerita metasedimentary rocks were intruded by the Rubio diorite, mostly coarsely banded hornblende and biotite diorite gneiss. These two formations were mapped, named, and described by Miller [14] and were later mapped on a larger scale in a section across the western San Gabriel Mountains by Oakeshott.[15] The Placerita and Rubio formations have been irregularly intruded by the very much later granitic plutonic rocks, which probably average a granodiorite in composition. The plutonic rocks exposed nearest the Placerita field include chiefly pinkish, gray and light brown biotite granite and granodiorite. The ages tentatively assigned are Paleozoic (?) for Placerita and Rubio, and Upper Jurassic (?) for the granitic series.

Shattered basement rock in the San Gabriel fault zone in upper Placerita Canyon has been reported as the reservoir rock for a light oil, probably derived from an Eocene source.[16]

Paleocene and Eocene Formations

Kew [17] first recognized a hard sandstone exposed in Elsmere Canyon as Domengine and later Brown and Kew [18] called attention to "hard sand and conglomerate of probable Eocene age" cored in a Placerita well in sec. 31, T. 4 N., R. 15 W., S.B. An exposure of lower Pliocene Elsmere sandstone lying unconformably on middle Eocene Domengine gray pebbly sandstone may be seen in a branch of upper Elsmere Canyon 2 miles south of Placerita Canyon. The Elsmere strikes N. 70° E. and dips 10° N.; the Domengine strikes N. 20° W. and dips 35° W. Nelson-Phillips Oil Company discovery well, Kraft 1, in the southeast quarter of that section, bottomed in hard shale at 2242 feet, which is probably Eocene, but found it barren and plugged back to 717 feet to obtain production from the Sunshine Ranch-upper Pico. Dr. Kew [19] has informed the writer that Standard Placerita 3 cored steeply dipping Eocene shale at 1050 feet; no Eocene production was obtained.

Brecciated hard conglomerate and sandstone of the Paleocene Martinez formation crops out in slivers along the San Gabriel fault zone approximately 5½ miles east-southeast of Kraft 1.[20] Eocene rocks encountered in wells in Elsinore and Whitney Canyons, have yielded higher gravity oil than that from the Pliocene formations. Eocene formations may be a rather important source of petroleum, as well as a reservoir, in the region of the Newhall field. They are widely distributed north and west of the crystalline basement rocks of the western San Gabriel Mountains.

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[14] Miller, W. J., Geology of the western San Gabriel Mountains of California: Univ. California Los Angeles, Pub. Math. Phys. Sci., vol. 1, no. 1, 114 pp., 1934.

[15] Oakeshott, Gordon B., Geology and mineral deposits of the western San Gabriel Mountains, Los Angeles County: California Jour. Mines and Geology, vol. 33, pp. 215-249, 1937.

[16] Brown, Arthur B., and Kew, W. S. W., Occurrence of oil in metamorphic rocks of San Gabriel Mountains, Los Angeles County, California: Am. Assoc. Petroleum Geologists Bull., vol. 16, pp. 777-782, 1932.

[17] Kew, W. S. W., Paper read before Geology and Paleontology Club, California Inst. Technology, March 31, 1931.

[18] Brown and Kew, op. cit., p. 780.

[19] Written communication.

[20] Clements, Thomas, and Oakeshott, Gordon B., Lower Eocene (Martinez) of the San Gabriel Mountains, southern California (abstract): Geol. Soc. America, Proc. 1934, p. 310, June 1935.

Mint Canyon Formation

The Mint Canyon formation, exposed north of the San Gabriel fault in the area mapped, and widely distributed for several miles to the north and northeast, has been mapped and described in some detail by Jahns.[21] Numerous other workers have attacked its problems, particularly students of the California Institute of Technology and the University of Southern California, and petroleum geologists. The formation is entirely of continental origin and consists of conglomerate; coarse- to fine-grained gray, buff, and greenish sandstones; red beds; fine lake sediments including clays, mudstones, and siltstones; and thin beds of tuff at various horizons. In the area mapped the formation is more than 2400 feet thick. Just north of this area Jahns [22] has measured a thickness of 4044 feet across Puckett Mesa. He believes it to be upper Miocene in age, as it lies unconformably on the lower Miocene Tick Canyon and Vasquez formations and unconformably below upper Miocene Modelo beds.

A marked angular unconformity between fossiliferous Modelo sandstone and shale and Mint Canyon sandstone and conglomerate is exposed on the south slopes of Reynier Canyon near the center of the south line of sec. 35, T. 4 N., R. 15 W., S.B., 4 miles due east of the crossing of Sierra Highway at Placerita Canyon. According to petroleum geologists,[23] the Modelo in question has yielded foraminifera of Delmontian age. Consequently the Modelo-Mint Canyon unconformity in this locality may belong just below the Delmontian stage of upper Miocene time. Dibblee [24] has recognized and named the Rafaelan orogeny of similar age in the Los Alamos trough and San Rafael Mountains northeast of Santa Maria, Santa Barbara County.

In the Placerita area, the Modelo includes gray and brownish conglomerate beds, well-stratified thin pebbly sandstone, dark greenish sandstone and mudstone, thin brown calcareous beds, clay shales, and beds of white vitreous tuff. At fossil localities, noted on the geologic map, numerous small gastropods were found which Dr. G. D. Hanna indicated were fresh-water forms including *Amnicola*. On the Sierra Highway at the north boundary of the Sylmar quadrangle, the gastropods were found in brown shales, interbedded with light-brown sandstone and a tuff bed 1 foot thick; on that highway 3400 feet NE. of the previous locality, in greenish mudstone interbedded with brown shale and conglomerate; and 3000 feet due west of the last named, in a gray-brown medium-grained calcareous sandstone bed containing abundant carbon fragments. This section of the Mint Canyon appears to be of lacustrine origin.

Detailed mapping in this area, and in other parts of the San Fernando quadrangle, shows that the Mint Canyon formation does not crop

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[21] Jahns, Richard H., Stratigraphy of the easternmost Ventura basin, California, with a description of a new lower Miocene mammalian fauna from the Tick Canyon formation: Carnegie Inst. Washington Pub. 514, pp. 147-194, 1940.

[22] Op. cit.

[23] Oral communications, sources confidential.

[24] Dibblee, T. W., Jr., Geology of southwestern Santa Barbara County, California: California Div. Mines Bull. 150, 1949 (in press).

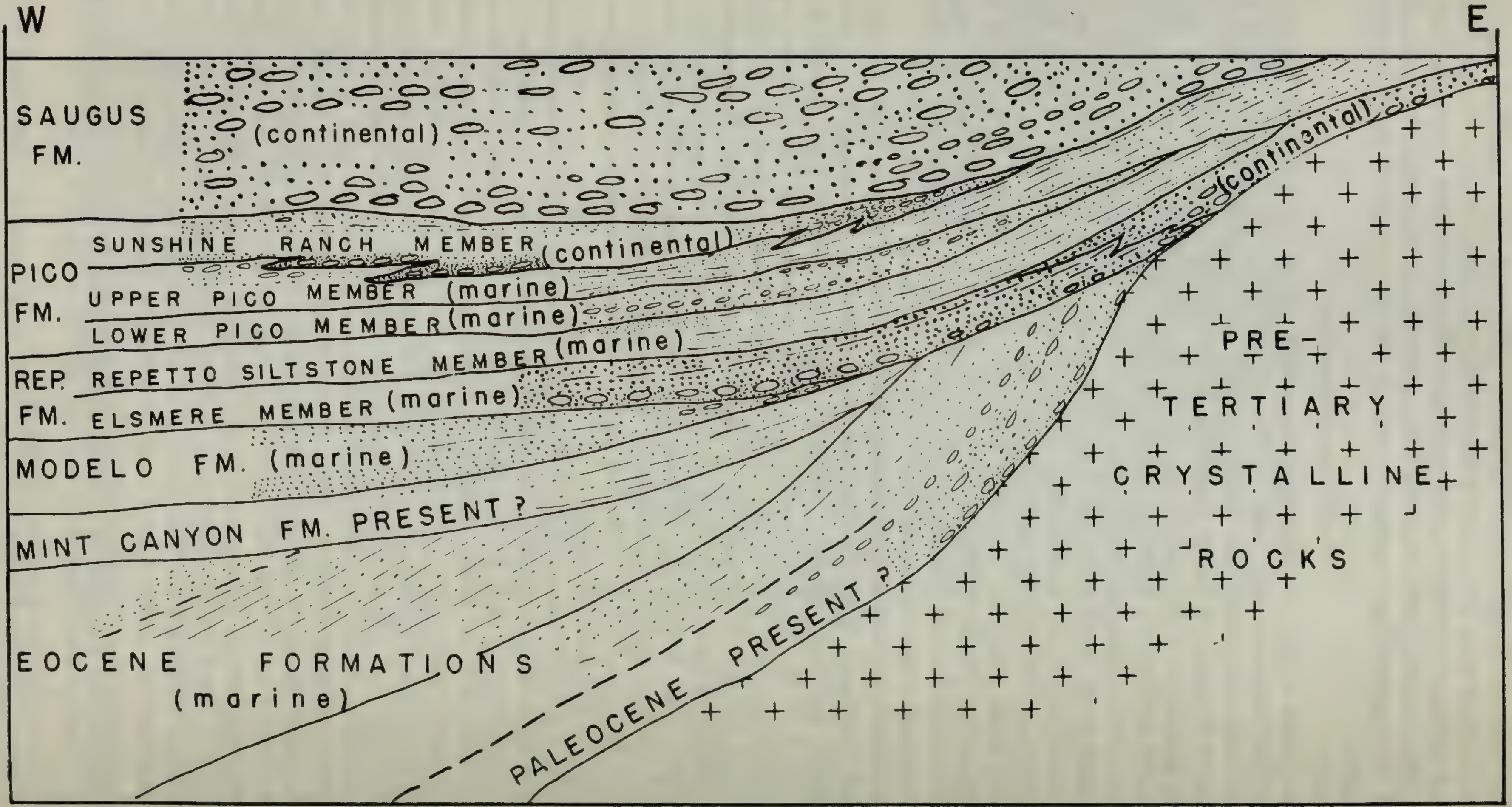
W
E
SAUGUS FM.
(continental)
PICO FM.
SUNSHINE RANCH MEMBER (continental)
UPPER PICO MEMBER (marine)
LOWER PICO MEMBER (marine)
REP. FM.
REPETTO SILTSTONE MEMBER (marine)
ELSMERE MEMBER (marine)
MODELO FM. (marine)
MINT CANYON FM. PRESENT ?
EOCENE FORMATIONS (marine)
PALEOCENE PRESENT ?
(continental)
PRE-TERTIARY CRYSTALLINE ROCKS

FIGURE 2. Schematic diagram showing Cenozoic sediments in eastern Ventura Basin south of San Gabriel fault zone in late Saugus time. Section about three miles long. Not to scale.

out south of the San Gabriel fault. However, it may be present at depth west of the Placerita field.

Repetto Formation

The name Repetto formation is here used for the lower Pliocene sedimentary rocks, including the basal Elsmere member and the Repetto siltstone member.

Elsmere Member. The Elsmere member of the lower Pliocene Repetto formation is best exposed in the type locality in Elsmere Canyon, and to the south and east around the western border of the San Gabriel Mountains. It has yielded a rich basal Pliocene (Jacalitos) fauna fully described by Grant and Gale.[25] It consists of coarse marine sandstone, conglomerate, siltstone and mudstone, commonly oil-saturated, and dips off the crystalline basement rocks on which it lies unconformably. Contact with Eocene beds in upper Elsmere Canyon is unconformable.

Northward from the Elsmere Canyon region, along the Elsmere-crystalline-rock contact, fossiliferous marine basal Elsmere loses its fossils and appears to grade into coarse conglomerate and sandstone of continental origin. In the same direction, it is overlapped by marine beds containing a middle Pliocene San Diego fauna (Grant and Gale locality 201).[26]

Repetto Siltstone Member. The Repetto siltstone member of the lower Pliocene Repetto formation is exposed in two small areas north of the San Gabriel fault. It consists of gray and chocolate-brown shale, siltstone, mudstone, and thin-bedded calcareous sandstone. Grant and Gale[27] (locality 232) found a lower Pliocene molluscan fauna in the northeast corner of sec. 32, T. 4 N., R. 15 W., S.B. There a well-marked angular unconformity between Repetto siltstone and Mint Canyon lake beds, the latter including a prominent white tuff bed, is well-exposed. In the same region Sunshine Ranch sandstone and conglomerate unconformably overlies the Repetto with clear angular discordance. Repetto siltstone beds, immediately above the lower unconformity, contain a lower Pliocene fauna described by Grant and Gale[28] from their locality 232.

The second area of Repetto siltstone is best exposed along the Southern Pacific railroad about a quarter of a mile southeast of Honby School. Similar lithology and similar fossil molluscs make it appear probable that the exposure should be correlated with that previously mentioned. In this instance the Repetto-Mint Canyon contact is not well exposed but attitudes in both formations are such that no large angular discordance seems likely. The Sunshine Ranch beds lie unconformably on the Repetto with markedly lower dips, and overlap onto the Mint Canyon a third of a mile south of the railroad.

The age relationship between the Elsmere and Repetto siltstone members of the Repetto formation is not certain. The term ''Repetto formation'' is applied to all lower Pliocene beds; ''Elsmere member'' is used for lower Pliocene beds including the typical Elsmere fauna as described by Grant and Gale; and ''Repetto siltstone'' is used for the siltstone and fine sandstone beds of lower Pliocene age. The two members may be contemporaneous, in part, although from mapping farther south, the writer believes that the siltstone member probably overlies Elsmere.

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[25] Grant, U. S. IV., and Gale, H. R., Pliocene and Pleistocene mollusca of California: San Diego Soc. Nat. History Mem., vol. 1, 1931.

[26] Op. cit., p. 33.

[27] Op. cit.

[28] Grant, U. S., IV, and Gale, H. R., Pliocene and Pleistocene mollusca of California: San Diego Soc. Nat. History Mem., vol. 1, p. 104, 1931.

Pico Formation

The term ''Pico formation'', in accordance with present common usage, is here applied to members of middle and upper Pliocene age. Three members are recognized: lower Pico marine middle Pliocene, upper Pico marine upper Pliocene, and the continental upper Pliocene Sunshine Ranch member.

Lower Pico Member. The Lower Pico member, which in the area mapped reaches a maximum thickness of 700 feet, appears south of the Placerita fault where it dips generally northwest off the pre-Tertiary crystalline rocks. A sliver of steeply dipping brownish sandstone and conglomerate in the San Gabriel fault zone is tentatively correlated with it; no middle Pliocene has been recognized north of that fault. The middle Pliocene beds include white pebble conglomerate, coarse sandstone with fine sandstone lenses, and thin brown siltstone beds, very much crossbedded and irregularly impregnated with petroleum. Live tar seeps occur just west of the Whitney fault 4000 feet due south of Whitney Canyon at the base of a boulder conglomerate which lies on Repetto siltstone and fine brown sandstone.

Lower Pico shows no marked angular discordance with the underlying Elsmere member but gradually overlaps the latter and lies directly on the crystalline rocks at Whitney Canyon and north. The Lower Pico is overlain by Upper Pico at Placerita Canyon and by Saugus and Sunshine Ranch beds south of Placerita Canyon, but mapping from the south strongly suggests the Lower Pico member never extended much farther north but probably thinned to the Lower Pico shoreline not far from the San Gabriel fault zone. Lower Pico in the vicinity of Placerita Canyon and north may well be partly continental in origin.

Grant and Gale [29] fossil locality 201 is not far from the base of the Lower Pico member 2800 feet south of Whitney Canyon. They say of that locality: [30]

''The most easterly occurrence of the middle Pliocene faunal zone may be at locality 201 S.D.S.N.H. in the upper horizon at Elsmere Canyon. Here the section is very thin, probably near the apex of the marine Pliocene wedge, and the upper and lower littoral zones are separated by only 200 or 300 feet of oil-stained shaly sandstone . . . The fauna at locality 201 is poorly preserved and fragmentary; but it contains several fragments of *Pecten estrellanus* variety *cerrosensis,* and as its stratigraphic position corresponds to that of other occurrences of the middle Pliocene fossiliferous horizon, it is here assigned tentatively to the upper littoral zone. A small *Ficus* also occurs at this locality; but it is not well enough preserved to show whether it is a typical Ficus or a *Trophosycon* that had survived a short time after the sea had begun to retreat, living on there into the middle Pliocene as other individuals of the same species did at San Diego. It is, of course, possible that this

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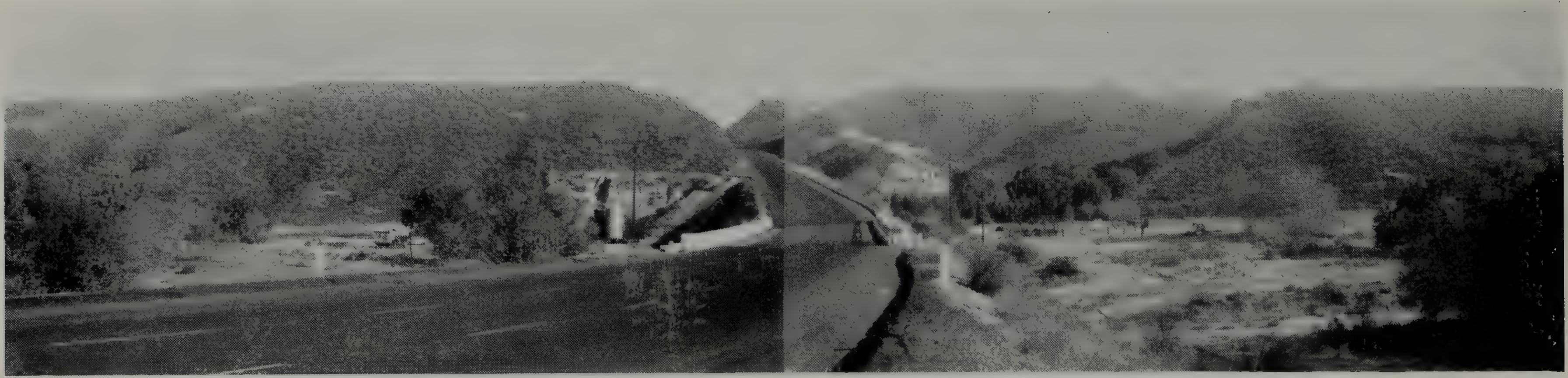
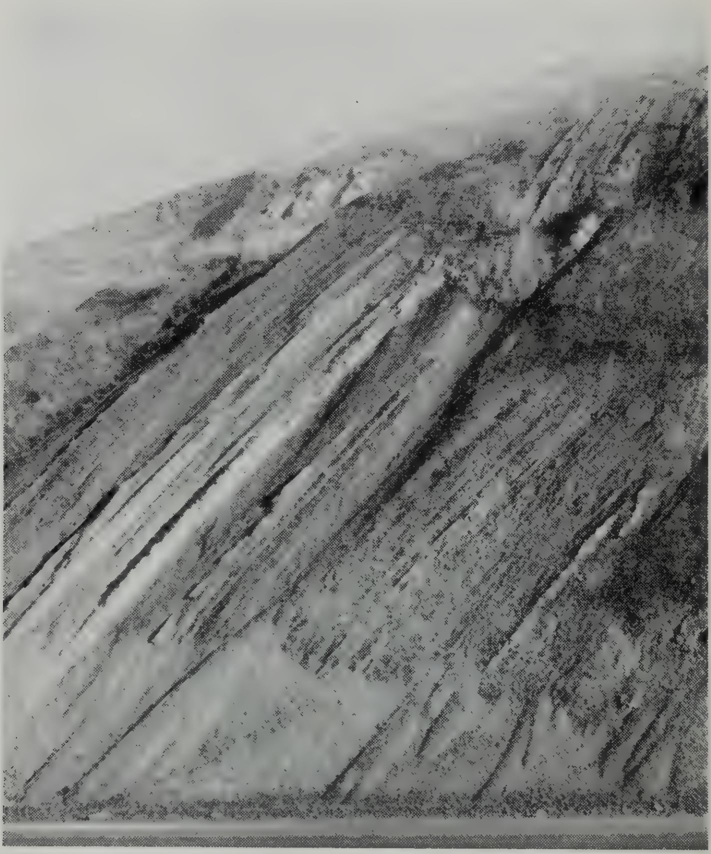
[29] Grant, U. S., IV, and Gale, H. R., Pliocene and Pleistocene mollusca of California: San Diego Soc. Nat. History Mem., vol. 1, 1931.
[30] Op. cit., p. 33, and diagram B (p. 31).



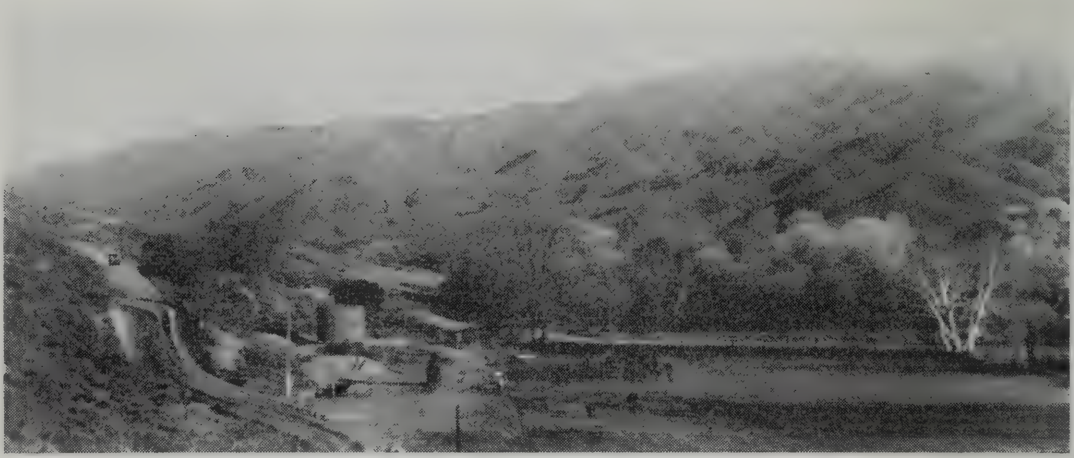
VIEW NORTH ALONG SIERRA HIGHWAY TOWARD PLACERITA CANYON FIELD, NOVEMBER 1948

The main ridge is made up of gently westward-dipping older terrace gravels. The underlying Saugus coarse sands and gravels are best exposed in the highway cuts and cuts made for well and tank locations.



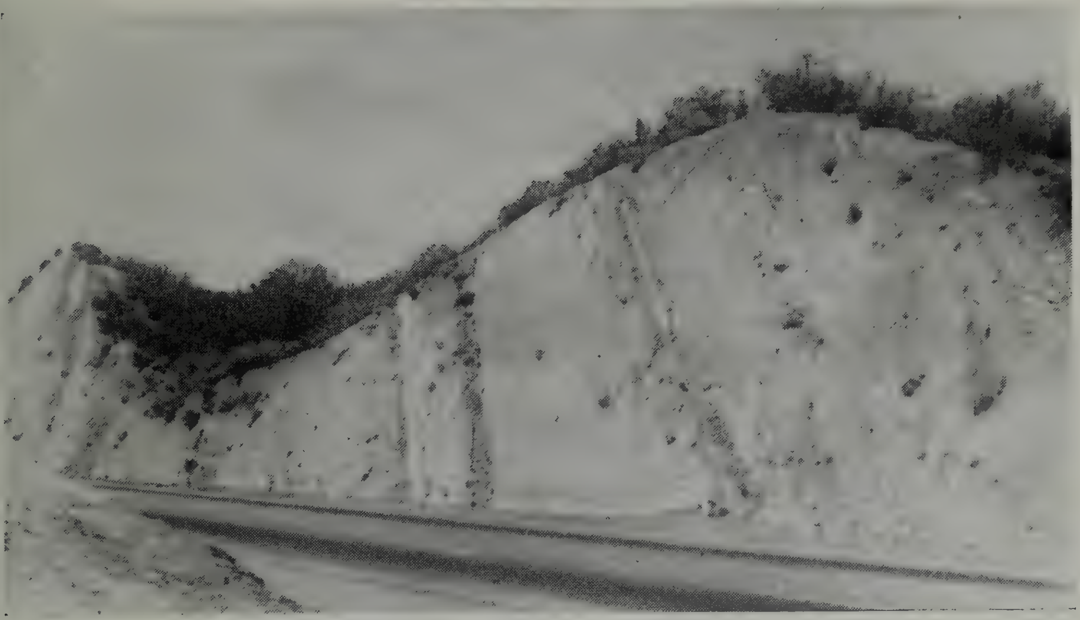
A, MINT CANYON LAKE BEDS

Beds include 8-inch layer of white tuff. This cut is on southeast side of Sierra Highway at boundary of Sylmar and Humphreys quadrangles.



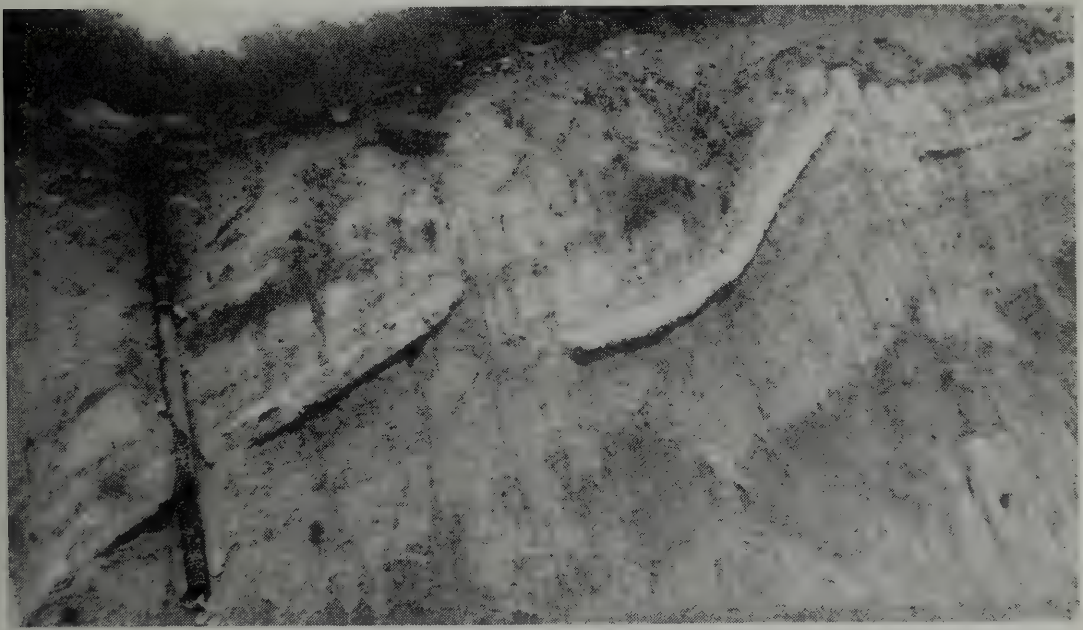
B, VIEW EAST UP PLACERITA CANYON FROM BRIGE ON SIERRA HIGHWAY

Standard well Placerita No. 6 is on the far left. Saugus beds, underlain by lower Pico, dip toward the camera in the low foothills; the higher hills in the background are pre-Tertiary crystalline rocks.



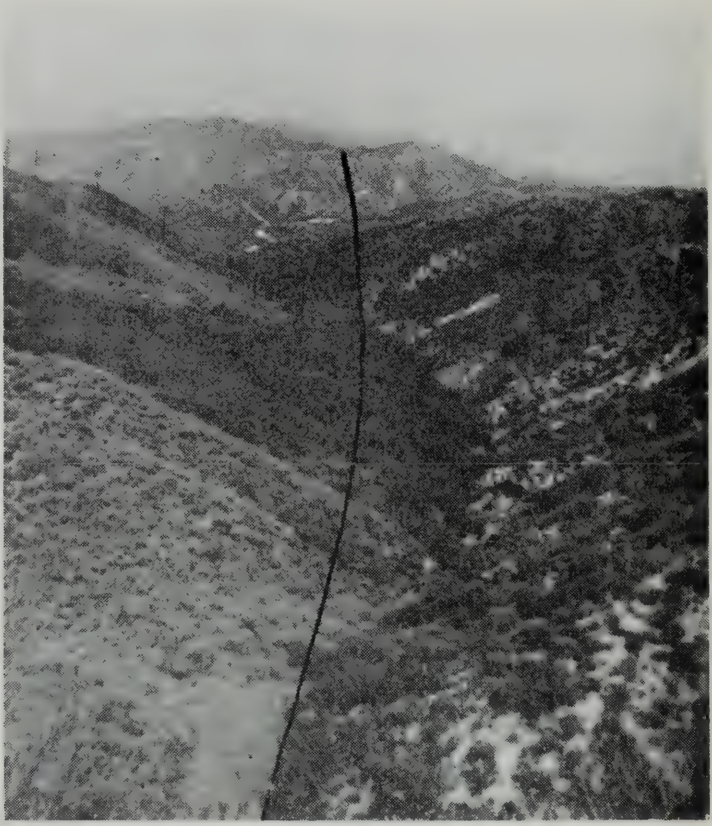
A, MINT CANYON LAKE BEDS

North-dipping sandstone, mudstone, and conglomerate on Sierra Highway three-quarters of a mile south of Solamint.

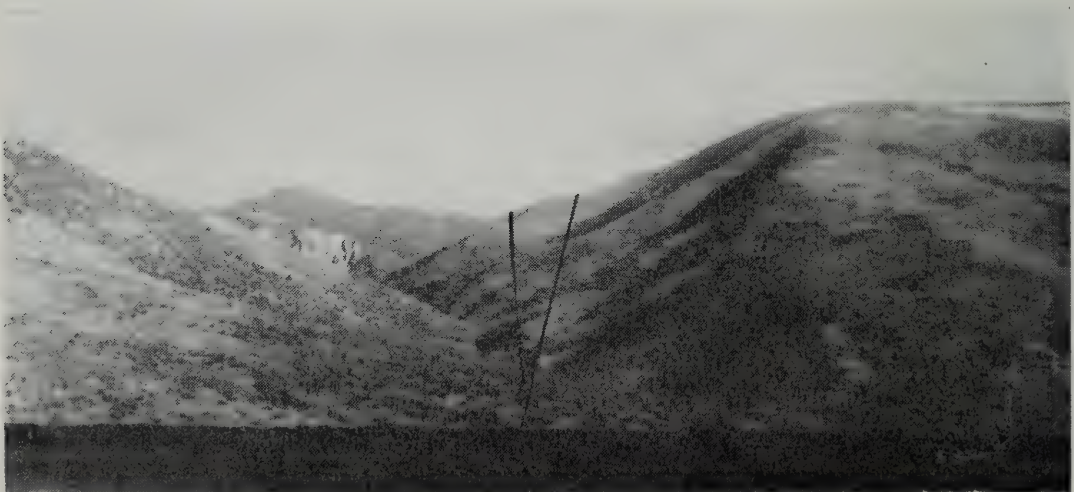


B, WHITE FRESH-WATER LIMESTONE

Bed 18 inches thick, with colored sandstones and mudstones of the Sunshine Ranch member of the upper Pico formation. On Sierra Highway, looking northwest near southeast corner sec. 30. Note two small faults.



A, VIEW N. 60° W. ALONG SAN GABRIEL FAULT
From first saddle west of Sierra Highway. Saugus gravels on right dipping steeply south into fault; gently folded older terrace deposits on south side of fault.



B, VIEW SOUTHEAST ALONG SAN GABRIEL FAULT ZONE FROM SIERRA HIGHWAY upper horizon in Elsmere Canyon is just another fossiliferous lens of the better known fossil zone found below, and may not have the significance here attached to it. In that case it would probably be necessary to assume that the upper littoral zone had been washed away before the deposition of the thin layer of overlying alluvial gravels of the Saugus formation.''

Detailed mapping south of Whitney Canyon in the vicinity of locality 201, and also north of that canyon, has revealed evidence that the lower Pico (San Diego) is a separate mappable unit unconformably lying on the Elsmere member of the lower Pliocene Repetto formation and overlapping it onto the crystalline rocks. Lower Pico is overlain by upper Pico beds just north of Placerita Canyon, and is unconformably overlain by the Saugus formation south of the canyon.

Upper Pico Member. The term ''Upper Pico member'' of the Pico formation is here applied to marine upper Pliocene beds which overlie, with apparent conformity, the lower Pico just north of Placerita Canyon. Here the Upper Pico member is unconformably overlain by the Saugus formation.

Upper Pico is best exposed in the Placerita anticline northeast of the Placerita discovery well. In that region it consists of well-stratified coarse brown and buff sandstone, medium-grained sandstone, and conglomerate; coarse- to fine-grained dry tar sandstone is common; some yellowish-green sandstones are present. In the field it was judged to be marine, although it may be continental in part; no fossils were found in the outcrops. Two branches of a dome on the Placerita anticline appear, with a reverse fault along the south limb of the south branch. At the northeast end of the south branch of the structure, basal Saugus beds of coarse sulphur-yellow and white sandstone and poorly sorted gravel dipping 20° NNE. lie unconformably on fine to coarse oil sandstone of the Upper Pico member, which dips 30° NNE.

Very little coring has been done in the Placerita field but fragments of cores were examined from Nelson-Phillips Kraft 1, the discovery well. They indicate that the well penetrated continental gravels (Saugus and Sunshine Ranch) to about 420 feet and then entered the Upper Pico zone consisting of alternating beds of fine gray sandstone, gray fossiliferous siltstone and shale, and coarse oil sand. Dr. Leo Hertlein[31] recognized ostracods and a ''species of *Cryptomya* resembling upper Pliocene forms in San Joaquin Valley'' in the siltstone. Word from a petroleum geologist[32] indicates the presence of uppermost Pliocene foraminifera in these beds. Casing in the well is perforated between 580 and 717 feet. Thus oil production appears to be coming from oil sands in the marine Upper Pico and possibly also from basal continental Sunshine Ranch beds which may here interfinger with the Upper Pico.

The Upper Pico member between the Placerita and San Gabriel faults includes light brownish poorly sorted fanglomerate, conglomerate, and beds of coarse greenish sandstone. Although mapped as Upper Pico, it is quite likely these beds are continental, in part, and that the region is one of gradation and intercalation of marine Upper Pico and continental brackish-water Sunshine Ranch members of the upper Pliocene.

Marine members of the Pico formation have not been recognized north of the San Gabriel fault.

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[31] Oral communication.
[32] Confidential source.

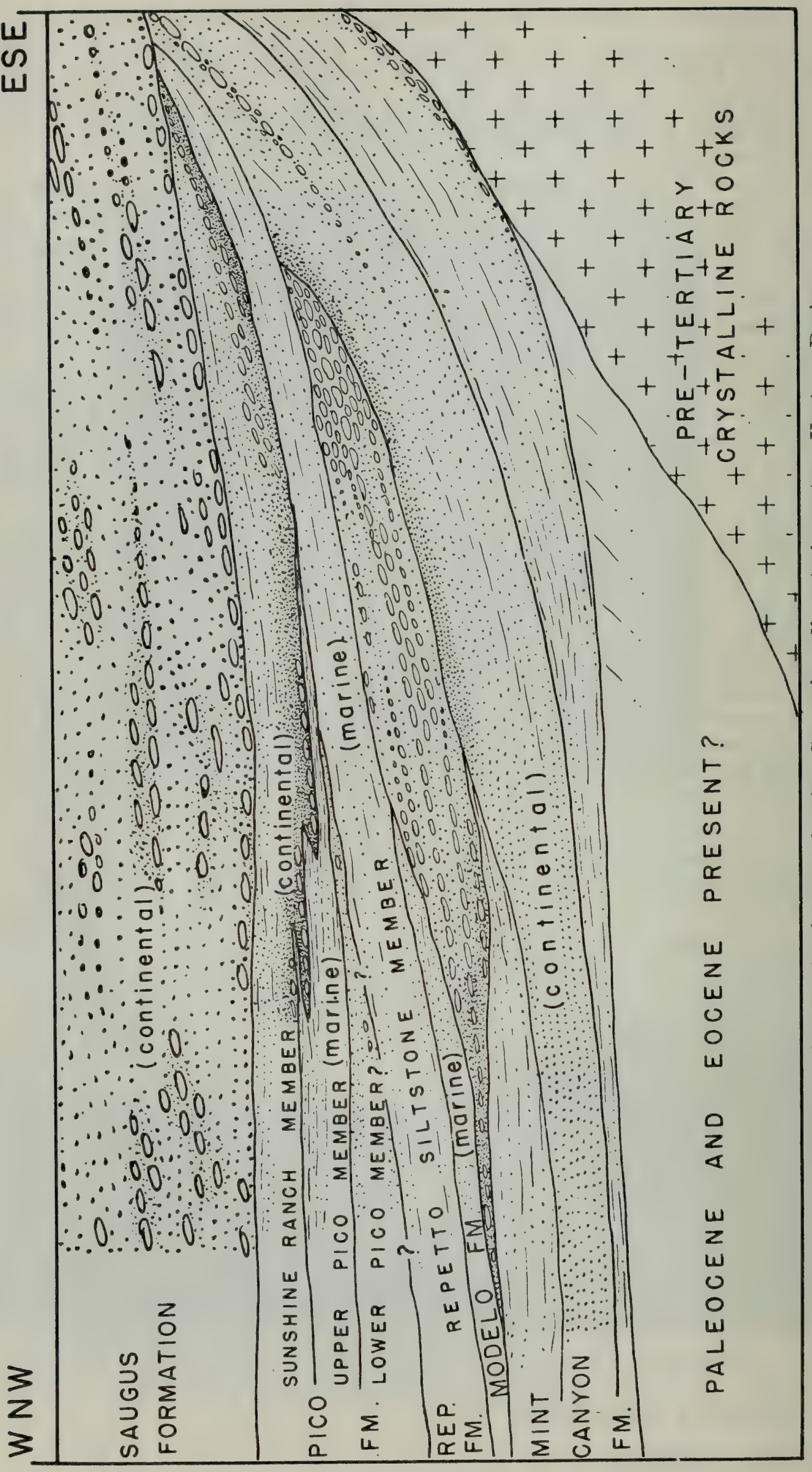
WNW
ESE
SAUGUS FORMATION
(continental)
SUNSHINE RANCH MEMBER
(continental)
PICO FM.
UPPER PICO MEMBER (marine)
(marine)
LOWER PICO MEMBER?
?
?
SILTSTONE MEMBER
REP. FM.
REPETTO FM
(marine)
MODELO FM
MINT CANYON FM.
(continental)
PALEOCENE AND EOCENE PRESENT?
PRE-TERTIARY CRYSTALLINE ROCKS

FIGURE 3. Schematic diagram showing Cenozoic sediments in eastern Ventura Basin north of San Gabriel fault zone in late Saugus time. Section about three miles long. Not to scale.

Sunshine Ranch Member. The term ''Sunshine Ranch member'' of the Pico formation is applied here to upper Pliocene continental beds lying below the continental lower Pleistocene Saugus formation and above marine beds commonly called Pico. The term has been modified from Hazzard's ''Sunshine Ranch formation'' used in a recent unpublished report.[33] Portions of that report, dealing with a part of the Santa Susana Mountains west and southwest of the Placerita area, are as follows:

> "Lithologically, the Sunshine Ranch formation is quite distinctive and field recognition of the unit was based upon rock characteristics in practically all cases. As originally mapped by W. S. W. Kew the rocks of the formation were grouped within the Saugus formation, hence the name here used is new. As typically developed the Sunshine Ranch beds are exposed in the foothill area north of Sunshine Ranch between the axial region of the Reservoir anticline and Balboa Avenue [west of San Fernando Reservoir]. This area is designated as the type locality.
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> "In the type area the basal portion of the Sunshine Ranch formation consists of about 20 feet of cross-bedded pebbly to cobbly sandstone which at its base locally includes boulders of the underlying Pico sandstones and shows irregular 'cut and fill' contact relations with the older beds. Above the basal sandstone is a coquina 'reef bed' which varies in thickness along the strike but averages about 35 feet. Following is an interbedded series of gray, coarse-grained to pebbly, friable sandstone and gray to greenish-gray very fine-grained sandstone, silty sandstone or sandy siltstone. These fine-grained greenish-gray beds are the most characteristic lithologic type of the formation. As a rule, their mere presence, even in thin beds, is indicative of their stratigraphic position.
>
> "Some of the fine-grained material is in massive beds 1 to 2 feet thick; other portions show a poorly developed shaly parting which is in part controlled by a fine lamination within the rock. The greenish-gray color is due at least in part to an abundance of unaltered biotitic mica. Most of the finer-grained material is angular to subangular in outline. Good rounding occurs only in the coarser component of the pebbly gray sandstones. At various horizons throughout the formation the silty sandstones or siltstones are limy and at some places soft, white limestone and impure bentonitic (?) clays are present.
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> "The number, thickness, and stratigraphic position of the coquina 'reefs' and fossiliferous beds are likewise quite variable.
>
> "A basal or near basal fossiliferous zone, usually a coquina 'reef bed' extends from the western limit of the formation as mapped west of Brown's Canyon, eastward at least to the east side of Balboa Avenue. The maximum vertical range of fossiliferous material is not known. . . .
>
> ". . . . In the vicinity of the type locality fossils occur at least as high as the middle of the formation and in the basal portion as many as three or four extremely fossiliferous zones can be mapped. Locally, the basal coquina beds are of sufficient thickness and extent to have been mined for lime . . . .
>
> "Macro-faunal samples from the Sunshine Ranch formation . . . . were reported as upper Pico or lower Pleistocene in age. One sample . . . . yielded a micro-fauna of brackish-water or lagoonal character of possible Pliocene age and brackish-water ostracods were reported in a sample . . . . collected very near the top of the formation . . . .
>
> "The general distribution of the marine, brackish-water, and fresh-water faunas in the Sunshine Ranch formation indicate that the bulk of the formation is definitely shallow-water marine or lagoonal, grading into fresh-water deposits toward the east. The change from shallow marine to fresh-water deposits is believed to occur in the general region between Balboa Avenue and lower San Fernando Reservoir for within those limits the basal coquina reef, as well as marine fossils higher in the formation, disappear.
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> "Correlation is made on basis of lithology, fauna, and stratigraphic position with the Sunshine Ranch formation north of the Santa Susana

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[33] Written communication from John C. Hazzard including extracts from his report to the Union Oil Company; published here by permission of that company.

> fault. Evidence has already been presented for the upper Pliocene age for the beds in that region and the same age is necessarily assigned to the Sunshine Ranch formation of the foothill belt."

Hazzard noted an ''angular unconformity with a maximum discordance of about 20°'' on Pico beds at the narrows in Brown's Canyon, six miles west of the San Fernando Reservoir, but at other localities little evidence of any angular discordance. He says: ''Tentatively, the two units (Pico and Sunshine Ranch) will be designated as regionally disconformable with local unconformable relations.''

In the Placerita field the Sunshine Ranch member is best exposed in deep road cuts along the Sierra Highway just north of the San Gabriel fault where it has a thickness of approximately 1300 feet and has been folded to form an asymmetrical anticline. A section paced along the highway is as follows:

San Gabriel fault	
Saugus formation	
Gravel and coarse sandstone	100 feet
Disconformity (?)	
Sunshine Ranch member of Pico formation	
Coarse light-grayish gravel; boulders up to 2 feet in diameter	100
Brown sandy mudstone	40
Light-grayish gravel	30
Brown sandy mudstone	30
Coarse grayish gravels	40
Gray sandstone, greenish-gray mudstone, light-brown sandstone, 4-inch bed white sandy limestone	40
Coarse gray gravel	20
Brown and greenish sandstone	40
Coarse gravel	20
Alternating reddish and greenish beds, white concretionary limestone beds, coarse sandstone, and conglomerate	90
Greenish and reddish mudstones and 2-foot bed white fresh-water limestone	50
Alternating pale-brownish, gray, and greenish sandstones and mudstone, thin white concretionary limestone, and coarse gray and brown sandstone	800
Total thickness Sunshine Ranch	1300±
Angular unconformity	
Mint Canyon formation	

Lithologic similarity between the Saugus and Sunshine Ranch is strong but several distinctions, in addition to stratigraphic position, were used in field mapping. There is a general color difference, the Sunshine Ranch being particularly marked by greenish shades and fewer red and brown beds, although both these latter are common. The thin white fresh-water limestone beds are rarely developed in the Saugus and their occurrence in a sequence of greenish-gray and reddish sandy mudstones is very characteristic of the Sunshine Ranch member. The lower part of the Sunshine Ranch on Sierra Highway includes a 3-foot bed of dark brownish titanomagnetite sandstone resembling a dry oil sand. Sunshine Ranch beds also bear a rather close resemblance to certain horizons in the Mint Canyon formation and the two formations might well be confused where stratigraphic position is not clear.

It is rather difficult to locate an exact contact between the Saugus and Sunshine Ranch because of the lithologic similarity and lack of angular discordance, but mapping just north of the San Gabriel fault shows that Saugus beds overlap the Sunshine Ranch eastward, onto the Repetto siltstone. However, the Sunshine Ranch probably originally thinned in that direction also, as the margin of the basin of deposition was approached. Recognition of the contact between Saugus and Sunshine Ranch beds from well logs is uncertain but stratigraphic position and the greenish color of the latter are most useful. Many geologists have recognized ''lower Saugus'' or ''upper Pliocene portion of the Saugus,'' probably conforming rather closely to ''Sunshine Ranch'' as used in this paper. Sunshine Ranch has been recognized in a number of the Placerita wells and probably has been penetrated by most of them.

A steeply north-dipping section of the Sunshine Ranch sediments is exposed by cuts along the overflow canal on the west side of the San Fernando reservoir, northwest corner of the Pacoima 6-minute quadrangle. It is lithologically almost identical with the Sierra Highway section described above but is more than 3000 feet thick. At the reservoir locality it unconformably overlies a fossiliferous lower Pico (San Diego) calcareous sandstone and is disconformably (?) below a section of the Saugus formation which is also more than 3000 feet thick.

Saugus Formation

The Saugus formation, as the term is used here, lies above the upper Pliocene continental Sunshine Ranch beds. It is overlain with angular unconformity by the oldest of the terrace deposits (older alluvium). In accordance with current usage and for reasons given below, it is regarded as lower Pleistocene in age. It is very widely distributed north and south of the San Gabriel fault and reaches a maximum thickness of about 2000 feet in this area. All of the Placerita wells start in Saugus beds or penetrate that formation at shallow depth after passing through Recent alluvium or terrace gravels. The Saugus formation increases in thickness westward toward the type locality near the town of Saugus.

The Saugus formation in the Placerita field consists largely of poorly sorted grayish, buff and brownish conglomerate and coarse sandstone, much of it crossbedded. Brown conglomerate-sandstone lenses are common but the sediments are predominately quite light colored. Lenticularity and crossbedding make determination of attitudes inexact, especially where dips are not high. Pebbles are largely various granitic rocks, gneisses, schists, and anorthosite; all are of local origin, showing derivation from the crystalline rocks of the San Gabriel Mountains and from the Tertiary sedimentary and volcanic series.

The Saugus-Sunshine Ranch contact seems to be a disconformable one, with little angular discordance, but north of the San Gabriel fault, southeast of the highway, the Saugus formation overlaps Sunshine Ranch and Repetto formations and finally lies directly on the Mint Canyon 1 mile southeast of the east boundary of the accompanying geologic map. In lower Whitney Canyon the Saugus formation overlaps Sunshine Ranch (?) onto lower Pico.

Age of the Saugus Formation. The work of Putnam and Bailey[34] has well established the age of the principal orogenic period in the Ventura basin as post-lower Pleistocene and pre-upper Pleistocene and offers good evidence of the lower Pleistocene age of the Saugus formation.

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[34] Putnam, W. C., and Bailey, T. L., Geomorphology of the Ventura region, California: Geol. Soc. America Bull., vol. 53, pp. 691-754, 1942.
Bailey, T. L., Late Pleistocene Coast Range orogenesis in southern California: Geol. Soc. America Bull. 54, pp. 1549-1568, 1943.

Their Pleistocene succession, based on paleontological evidence, is as follows:

Upper Pleistocene—Terrace gravels and fanglomerate, tilted in older parts.
Upper Pleistocene—Terrace deposits, dipping 8° to 20°.
Major unconformity
Lower Pleistocene—San Pedro = Las Posas = Waterfall's[35]
Saugus in Hall Canyon = Kew's[36] Saugus
on south side of south mountain west of Long Canyon.

Correlation of the beds exposed on the Sierra Highway north of the San Gabriel fault with Sunshine Ranch beds west of the lower San Fernando reservoir in the northwest corner of the Pacoima 6-minute quadrangle was previously mentioned, as was Hazzard's[37] statement indicating that upper Pliocene Sunshine Ranch beds of that area represent fresh-water deposits gradational into fossiliferous shallow-water marine or lagoonal beds to the west. The writer, in mapping the reservoir region, found a thickness of over 3000 feet of north-dipping Sunshine Ranch beds followed by another 3000 feet of Saugus beds. The contact between the two was placed 1500 feet south of the Pacoima-Sylmar quadrangle boundary at Sepulveda Boulevard. Later he found a horse tooth in Saugus gravels 800 feet stratigraphically above the base of the steep north-dipping Saugus at a point in a road cut on the west side of Sepulveda Boulevard 400 feet southeast of the Pacoima-Sylmar quadrangle boundary. Dr. Chester Stock, who examined the tooth, cautioned against regarding his statement as a final word because of the fragile and fragmentary condition, but had this to say concerning it:

> "The tooth is of course an upper tooth of a horse. I cannot be entirely sure of its position, although I suspect it is a molar tooth. The crown is definitely of the straight type that you would expect to find in *Equus*. What remains of the protocone, and that is a cross section seen near the root of the tooth, shows a style which has a flattened inner side. In other words, it doesn't have the indentation normally seen in teeth of *Equus*. The straightening on the inner face, however, may result from the position of the cross section close to the root end of the tooth. I would be inclined to say that it is a more primitive type of *Equus* than that found in the later Pleistocene deposits, but still definitely Pleistocene in age."

Extreme scarcity of fossils reported from the Saugus formation makes the occurrence of interest, particularly since the Saugus beds on Sepulveda lie disconformably (?) on a thick section of Sunshine Ranch and unconformably below slightly tilted terrace deposits. Dr. Stock's statement of age is not inconsistent with assignment of the Saugus formation to the lower Pleistocene.

Terrace Deposits and Alluvium

Remnants of older alluvial deposits uplifted and eroded to form terraces are very common in the region. A number of stages in the development of such terraces are recognizable but two are prominent in the Placerita field. The older deposit consists of coarse, poorly sorted fanglomerate, gravel, and sand, generally weathered to a brownish color and distinctly folded in some places. An exposure adjacent to the San Gabriel fault on the south side in a road cut on the Sierra Highway shows the older terrace deposits dipping westward at angles as high as 15° off Saugus beds with a 35° dip. West of the highway the San Gabriel fault has brought the terrace gravels in contact with Saugus-Sunshine Ranch beds. Thus the older unit of terrace gravels has been affected by faulting and mild folding. The older terrace deposits blanket the area of the most productive part of the new oil field in sec. 31, T. 4 N., R. 15 W., S.B., where they reach a thickness of as much as 500 feet.

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[35] Waterfall, Louis N., A contribution to the paleontology of the Fernando group, Ventura County, California: Univ. California Dept. Geol. Sci. Bull., vol. 18, no. 3, pp. 71-92, 1929.

[36] Kew, W. S. W., Geology and oil resources of a part of Los Angeles and Ventura Counties, California: U. S. Geol. Surv., Bull. 753, 1924.

[37] Op. cit.

The later terrace gravels of the area appear as benches along the north side of Placerita Canyon, undisturbed by folding or faulting as far as could be determined. The site of discovery of gold in California in 1842 is in alluvium at the base of these bench gravels in Placerita Canyon very near B. M. 1513. The bench gravels, as well as Recent alluvium in the canyon, have yielded placer gold. Thickness of the younger terrace gravels is as much as 175 feet.

Age of the two terrace deposits is probably upper Pleistocene, as they were deposited after the mid-Pleistocene Coast Range orogenesis and before Recent alluvium.

Stream sands and gravels of Placerita Canyon and the Santa Clara River constitute the principal Recent deposits; their maximum thickness is unknown.

STRUCTURE

General Features

The structure and Cenozoic history of the Placerita area are complicated by the fact that three important geologic provinces adjoin in this small region: the western end of the San Gabriel Mountain positive block, the northwestern portion of the Los Angeles basin, and the eastern end of the Ventura basin. That part of the Cenozoic record which is preserved shows that almost continual uplift of the San Gabriel block took place, at times at an accelerated rate, with folding, faulting, and readjustments around the margins of that competent crystalline block and consequent geologically rapid fluctuations of the shorelines and variety of sedimentation. This general picture of the structural history of the area finds supporting evidence in regional dip of the late Tertiary-Quaternary sediments off the pre-Tertiary crystalline rocks; very irregular marginal faults and folds, as well as the major San Gabriel fault system extending across the San Gabriel block into the Ventura basin; a large number of unconformities, from minor local disconformities to major regional unconformities; very rapid variations in thicknesses of formations and gradations through marine, lagoonal, lacustrine, and fluviatile sediments; and the large proportion of very coarse sediments in the Cenozoic sections.

Faults

San Gabriel Fault Zone. One of the major structural features of this area is the San Gabriel fault zone. It strikes generally N. 65° W. to northwest for more than 60 miles obliquely across the San Gabriel crystalline block from the south front of the range north of Pasadena to the Frazier Mountain thrust a few miles southwest of Lebec. It has many of the features of the San Andreas rift and probably is closely related to it in origin.

It is characteristic of the San Gabriel fault zone that a single fault plane can be traced for only 2 or 3 miles, and then the displacement appears to die out and to be absorbed by movement along another fault plane roughly parallel to the first. Near-parallel fault planes with narrow slivers between them, either uplifted or down-dropped, of folded and contorted sedimentary strata, are common. An example is the 500-foot-wide sliver of Lower Pico (?) beds apparently uplifted between two San Gabriel fault planes southeast of Sierra Highway. The Lower Pico (?) beds are steep, possibly overturned in part, and there is evidence of a sharp narrow anticlinal structure. These two fault planes dip steeply north. North of the north plane Saugus-Sunshine Ranch beds lie unconformably on Repetto siltstone which, in turn, lies with a strong angular unconformity on the Mint Canyon formation. South of the north plane Sunshine Ranch, Repetto, and Mint Canyon formations do not appear. In the same general area, a sliver some 1300 feet wide between the south plane of the San Gabriel fault and the Placerita fault (the latter merging with the San Gabriel fault 2 miles to the east) is a down-dropped block of Upper Pico beds folded to form a syncline. This would require an apparent 1000-foot post-Saugus vertical component of displacement on the Placerita fault, in which relative movement was down on the north side. On the south plane of the San Gabriel fault there is an apparent vertical component of displacement of 700 feet, up on the north side. At the highway the most logical section that can be drawn shows the north block to have been raised a minimum of 1500 feet. Just east of the highway Saugus beds on the south are folded against the fault to form a syncline, probably a continuation of the synclinal axis between the Placerita and south San Gabriel fault planes a mile to the southeast; continuation of this syncline farther west is uncertain. On the north block of the San Gabriel fault the south limb of the highway anticline is turned sharply down against the fault. This displacement was post-Saugus and, at least in part, post-older terrace.

The lack of Pico beds north of the San Gabriel fault is probably the result of relative upward movement of the north block along the fault, or at least a positive position of that block, during Pico time.

The apparent absence of the Mint Canyon formation just south of the San Gabriel fault and the great thickness and coarseness of that formation north of the fault could best be explained if an ancestral San Gabriel fault were present in Mint Canyon time (possibly originating earlier) and active upward movements of the south block were taking place with consequent deposition of Mint Canyon sediments adjacent to and north of the fault zone. The thickness of Mint Canyon beds just north of the fault at present (2400+ feet) is some indication of the magnitude of that movement.

Evidence for a considerable horizontal component of displacement along the San Gabriel fault may also be noted in the Placerita region. A contact between Tertiary sedimentary rocks and the pre-Tertiary crystalline rocks south of the San Gabriel fault in Placerita Canyon appears 2½ miles east of that point on the north side of the fault, suggesting right lateral movement of that general magnitude. A few miles east, in the Little Tujunga quadrangle, the long-established Pacoima Creek drainage system has an apparent right-angle offset along the trace of the San Gabriel fault zone, with a right-lateral displacement of nearly 1½ miles. In each case the movement indicated is probably only that of Quaternary time; there is little evidence of the magnitude of pre-Quaternary horizontal movement.

Evidence in the Placerita region shows the San Gabriel fault has probably been an important structural feature since at least as early as middle Miocene time with a minimum vertical displacement, south block relatively up, of over 2000 feet and a possible horizontal component of displacement of several miles during late Tertiary time; the direction of vertical movement was reversed in post-Saugus time, with the south block relatively down a minimum of 1500 feet and a probable right-lateral horizontal component of displacement of at least 2½ miles. Movement has continued into very late Quaternary time as shown by displacement of terrace deposits and by the preservation of geologically recent minor topographic effects.

Whitney Fault. The name Whitney fault is suggested for a probable north-striking transverse fault recognized by Walling,[38] which seemingly limits production at the east end of the Whitney Canyon area. It has no surface expression in Whitney Canyon and does not appear to have affected Saugus beds, but about a mile south of Whitney Canyon, Pico and Elsmere beds appear to be faulted against Eocene sandstone and conglomerate in Elsmere Canyon. Production on the east of the Placerita field may be limited, in part, by this fault. Changes in attitudes of Pico and Elsmere beds adjacent to the fault south of Whitney Canyon suggest some left-lateral horizontal movement with a vertical component also; the west block is the upthrown side. The Whitney fault may be post-Pico and pre-Saugus in age; it may die out toward the north before being cut off by the San Gabriel fault.

Other Faults. On the highway, six thousand feet southwest of Solemint, locally contorted Mint Canyon beds appear on the northwestward projection of the trace of a pre-Pliocene fault, described by Kew [39] and shown on his geologic map in the Sand Canyon area, a few miles to the southeast. Movement along the fault seems to die out gradually to the northwest from Sand Canyon and to be largely absorbed in contortions of the Mint Canyon beds at Sierra Highway.

Another fault, possibly of local importance, strikes east-northeast toward the Placerita fault on the north side of Placerita Canyon. It is a reverse fault, dipping 75° S., and has brought Upper Pico beds on the south side up into contact with Saugus beds on the north. It lies parallel to, and between, the axis of a small syncline and axis of the southwest-plunging Placerita anticline. This fault, and adjacent flexures north and south of it, seems related to right lateral movement along the main San Gabriel fault.

Folds

General regional dips of the Tertiary sedimentary formations in the Placerita Canyon field are off the pre-Tertiary crystalline rocks toward the north and northwest. Faulting and accompanying folding, beginning as early as pre-Mint Canyon time, have superimposed a number of complex subordinate structures. In the movements involved the older crystalline rocks have behaved essentially as a competent block, undergoing intermittent elevation with adjustments within that block accomplished by faulting and shearing. Around the margins of the crystalline block the sedimentary strata have reacted, according to their competence and the local intensity of stresses applied, by development of a discontinuous series of synclines and anticlines of local extent. A number of these, as may be seen from the geologic cross section, are closely related to the faults, local synclines developing on the downdropped blocks and anticlines on the upthrown blocks. Apparently accumulating stresses were first relieved by folding and as such folding was renewed and continued fault movements resulted.

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[38] Walling, R. W., Report on Newhall oil field: California Div. Oil and Gas, Summary of operations, vol. 20, no. 2, p. 46 and plate I, 1934.

[39] Kew, W. S. W., Geology and oil resources of part of Los Angeles and Ventura Counties, California: U. S. Geol. Survey Bull. 753, 1924.

Placerita Nose. The main Placerita structure is a poorly defined nose involving Upper Pico and older terrace beds which generally dip northwestward off the crystalline rocks in the area between Whitney Canyon and the San Gabriel fault. An axis on this structure, the Placerita anticline, trends N. 70° E. across the junction of Placerita Canyon and Sierra Highway. About half a mile northeast of the highway it divides to form two minor axes; plunge is southwestward but a closed high is developed, exposing Upper Pico beds, in the area of the divided axis; closure is on the northeast where the beds are downfolded against the San Gabriel fault. Northwest of the highway in sec. 31, T. 4 N., R. 15 W., S.B., the older terrace deposits, with flat to gentle west dips, tend to obscure the older structure, but underlying Saugus beds dip from 15° to 30° NW.; approaching the San Gabriel fault, their strike changes to near-parallelism with the fault and dips increase to 35° N. Therefore, there is good closure to the north against the fault, a strong regional plunge, averaging about 10°, toward the west and southwest, and minor closure on the south. The structure narrows rapidly to the east and, after rising to a minor dome exposing Upper Pico beds, closes in the narrow syncline between the Placerita fault and the south plane of the San Gabriel fault.

Highway Anticlines. Two well-defined northwest-trending anticlines appear crossing the highway north of the San Gabriel fault. The southerly of the two, involving Mint Canyon, Sunshine Ranch, and Saugus beds, is a reflection of uplift of the north block of the San Gabriel fault. On the south limb Saugus and Sunshine Ranch beds are turned steeply down against the fault, but on the north limb very gently dipping Sunshine Ranch strata lie on the steeply dipping locally-contorted Mint Canyon formation. After the thick Mint Canyon beds had accumulated in this downdropped area north of the San Gabriel fault, and before Sunshine Ranch beds were deposited, a reversal of movement began on the fault and Mint Canyon strata were folded to form an asymmetrical anticline with steep north limb and very gently tilted south limb. Deposition of the Sunshine Ranch-Saugus beds took place across a relatively inactive San Gabriel fault; then, in post-Saugus time, renewed uplift and folding of the north block developed the later Sunshine Ranch-Saugus anticline with its steep south limb and very gentle north limb.

The northern highway anticline shows steep dips on both limbs and a 25° W. plunge, bringing down Repetto siltstone, Sunshine Ranch, and Saugus strata in turn around the west end. The anticlinal axis curves southeast and is cut off by the pre-Pliocene fault[40] previously mentioned. In the history of development of this anticline it is clear that post-Mint Canyon-pre-Sunshine Ranch folding and faulting took place and that folding was renewed in post-Saugus time.

Other Folds. Several minor folds have previously been mentioned in connection with faults. A series of tight steep-limbed synclines occurs east of Sierra Highway between the San Gabriel fault and pre-Pliocene fault. A number of these were probably developed principally prior to the time of deposition of Sunshine Ranch beds, as they could not be clearly recognized in the gently dipping Sunshine Ranch-Saugus formations northwest of the highway.

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[40] Kew, W. S. W., op. cit.

Table 2. Outline of the Geologic History

I. Pre-Tertiary
   - A. Deposition of unknown thickness of the Placerita marine (?) sediments, including limestone; possibly in Upper Paleozoic time.
   - B. Intrusion of Rubio diorite and metamorphism of Placerita sedimentary rocks to form schists and marble; accompanying mountain building in late Paleozoic (?) time.
   - C. Upper Jurassic (?) granitic intrusion and accompanying orogeny.

Unrecorded interval

II. Paleocene-Eocene
   - A. Deposition of marine conglomerate, sandstone, and shale of the Martinez formation. (Not certainly known to have been deposited over the Placerita area, but remnants remain as slivers in San Gabriel fault zone 5 miles to southeast.)
   - B. Deposition of marine sandstone, shale, and conglomerate of Eocene age; including probable Domengine formation.

Folding and erosion

Beginning of movement on San Gabriel fault, north block down (?)

III. Upper Miocene
   - A. Deposition of more than 2400 feet of Mint Canyon coarse continental sediments, lake beds, and thin tuff beds; sediments partly derived from uplifted south block of San Gabriel fault.
   - B. Post-Mint Canyon uplift of north block of San Gabriel fault; probably also right-lateral horizontal movement along the fault.

Continued uplift and erosion

IV. Lower Pliocene
   - A. Deposition of 100+ feet of Elsmere sands and gravels on the pre-Tertiary crystalline rocks in shallow water at the shoreline of a sea from the west and southwest; gradation northward into continental deposits south of San Gabriel fault.
   - B. Deposition of Repetto silt and fine sand in slightly later seas which extended farther to the north and northeast.

Renewed uplift and erosion of north block San Gabriel fault

V. Middle Pliocene
   - A. Deposition of about 700 feet of lower Pico shallow-water marine sand, gravel, and silt overlapping the Elsmere beds south of the San Gabriel fault. Lower Pico seas probably did not extend north of the San Gabriel fault in the Placerita area. North block of fault above sea level.

VI. Upper Pliocene
   - A. Deposition of about 1000 feet upper Pico shallow-water marine sand, gravel, and mud. Gradational, especially in upper part, into the lagoonal, brackish-water, and landlaid Sunshine Ranch beds deposited widely across the San Gabriel fault zone. North block of San Gabriel fault above sea level during Upper Pico; entire area, north and south, above sea level in Sunshine Ranch time.

VII. Lower Pleistocene
   - A. Deposition of 2000 feet of coarse continental sands and gravels of the Saugus formation around the margin of the rising crystalline rock mass and across the San Gabriel fault zone; fault relatively inactive during deposition of Sunshine Ranch and Saugus beds.

VIII. Middle Pleistocene
  A. Principal orogenic epoch, coinciding with Coast Range orogeny. Uplift, faulting, and shearing of San Gabriel crystalline massif, with severe folding and faulting of the marginal stratified rocks of Saugus age and older. Sharply renewed movement along the San Gabriel fault, involving a probable right-lateral horizontal component of displacement of more than 2½ miles, with apparent vertical component amounting to a 1500-foot uplift of the north block at Sierra Highway, but varying widely along the strike of the fault. Principal migration of petroleum into the reservoir rocks began at this time.

Erosion and continued orogenic movements

IX. Upper Pleistocene
  A. Deposition of older alluvium along stream valleys and in alluvial fans.
  B. Continuation of uplift and faulting with slight westward tilting of older alluvial deposits to form the older terraces.
  C. Continued deposition of coarse alluvium, and vertical uplift, resulting in in the younger group of terrace deposits.

X. Recent
  A. Deposition of recent alluvium in stream valleys and development of present land forms, accompanied by probable continued uplift and local movements along faults.

ORIGIN AND ACCUMULATION OF THE OIL

In the Placerita field the oil occurs in the Sunshine Ranch and Upper Pico members of the upper Pliocene Pico formation. Sunshine Ranch beds are highly lenticular crossbedded sandstone, sandy mudstone, and conglomerate, and grade into lenticular nearshore marine beds of the Upper Pico member. Producing zones range in thickness from a few feet to more than 250 feet, but no single oil sand reaches that maximum. Pico beds, in the new oil field, are unconformably underlain by steeply dipping Eocene sandstone and shale which have yielded no oil, although the nearby Whitney Canyon and Elsmere Canyon areas have produced some light oil from Eocene beds.

Source of the oil is not specifically known but petroleum has been found, or occurs in outcrops in the region, in several formations, including the Rubio gneiss and Placerita metasedimentary series, Eocene sediments, the lower Pliocene Elsmere and Repetto siltstone members, all of the members of the Pico formation, and probably also the lower Saugus formation. It is most likely that oil has migrated up-dip from source rocks of several ages including marine organic shales of the Eocene, Miocene, and Pliocene epochs. Migration and accumulation of petroleum may have begun as early as Miocene time, but accumulation in the present reservoir sands must have taken place during and after the mid-Pleistocene orogeny.

A combination of structural and stratigraphic factors accounts for the Placerita field. Chief among these are the westward-plunging Placerita nose of late Tertiary-Quaternary sediments off the pre-Tertiary crystalline rocks, and up-dip lensing in the Upper Pico-Sunshine Ranch members. Overlap of Upper Pico beds by Sunshine Ranch beds, and overlap of both these formations by Saugus beds may also have influenced accumulation. Minor flexures in the Placerita nose, particularly the Placerita anticline in the southern section of the oil field, and downfolding against the south side of the San Gabriel fault are important. The Whitney fault, Placerita fault, San Gabriel fault, branches of these, and minor folds associated with the faults are structural factors which, with up-dip thinning and lensing of the sediments, have limited extension of the field to the east.

FUTURE PETROLEUM DEVELOPMENT

At the close of 1948, proven acreage in the Placerita field was 240; reserves were estimated at 300,000 barrels.[41] At that time 20 wells were producing an average of 40 to 50 barrels a day of 11° to 16° gravity oil. On June 1, 1949, the writer considers a total of 430 acres have been proven, with 68 producing wells. About 10 of the latter were averaging 550 barrels a day of 21° to 23° gravity oil, and 20 wells were drilling in proven acreage.

In January 1949, Ramon Somavia brought in Juanita 1 near the north-central border of sec. 31, T. 4 N., R. 15 W., S.B., flowing 340 barrels per day of 22.4° gravity clean oil. Several additional wells in the north half of section 31 and along the south margin of section 30 have maintained that standard, the best to June 1949 being Somavia's Ashley 1, which was producing 1000 barrels per day. Oil is coming from the Upper Pico formation at depths of 1300 to 2100 feet. Surface geology in the region is obscured by the older terrace deposits, and drilling has left a gap of more than 1000 feet between the original area and the northern extension of the field, which produces higher-gravity oil. Whether the two pools are connected and the producing horizons are the same remains to be seen. However, the writer believes the producing horizon is the same, although lenses of oil sands in the two sections may not be continuous; the higher-gravity oil may be accounted for by greater depth and less chance for loss of the lighter fractions. Faulting, which is obscure at the surface, may separate the pools at depth.

Surface geology and wells drilled to early June 1949 indicate that limits of the new field are rather well defined. It is unlikely that production will extend farther east than the trace of the Whitney fault and its northern projection; the San Gabriel fault will mark the northern limit of the field. The southern limit of production seems to be parallel to the axis of the Placerita anticline and a fraction of a mile south of it. Some possibility of extension of the field to the west remains but several dry holes have been drilled west and southwest of section 31, including Ned Barmore Hays 1, abandoned at 2387 feet after no showings, Federal Oil Company Oakgrove 1 and York Oil Company York 5. Several wells being drilled in this region will help to define the western limit of the field.

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[41] Oil and Gas Jour., p. 278, Jan. 27, 1949.

LIST OF WELLS

Table 3. Wells drilled in Placerita Canyon area to and including 1934 *

Operator	Well S-T-R	Yr. comp. or aband.	Depth	Geology	Geology at bottom	Daily amts. oil, gas, water	Remarks	Status 6-1-49
Guiberson Oil Co. (formerly York Oil Co.; also Nile Oil Co.)	York 1 6-3-15	1920	Td 1394	No record		6 B/D 14° during late 1925	Disc. well. Pumped very heavy oil from 975 ft. Deepened to 1394 in 1921	Prod.
Guiberson Oil Co.	York 2 1-3-16	1924-25	Perf. liner landed 1402	No record		10 B/D 14° during late 1925	Producing in 1934	Prod.
Guiberson Oil Co.	York 3 6-3-15	1925-32	Td. 1598 Pgd. 1495	Qs to 1060 (?) Tsr 1060 (?) Tp 1460 (?)	Tp	14 B/D 12° in May 1934		Prod.
York Oil Co.	York 4 1-3-16	1932-33	Td 1563 Pgd. 1509	Qs to 1160 (?) Tsr (?) to bottom	Tsr (?)	19 B/D 11° 5%	Producing in 1934	Prod.
Sec. 31 Pet. Corp.	1 31-41-15	1930	Td 2008					Aband.
Morgan Pet. Corp.	Dunlap 1 31-4-15	1924	Td 983?					Aband.
General Pet.	Stabler 4 30-4-15	9-20	Td 3514					Aband.
Morgan Pet.	Stabler 3 31-4-15	9-20	Td 2640					Aband.
Occidental Pet.	1 31-4-15	8-22	Td 605					Aband.
North Star Min. & Dev. Co.	Shepard 1 1-3-16	8-31					Acquired by North Star March 1940	Aband.
Richfield Oil Co.	Shepard 1 1-3-16	12-24						Suspended

*Table 4. Wells drilled in Placerita Canyon schist area * (2½ miles east of Sierra Highway)*

Operator	Well S-T-R	Yr. comp. or aband.	Depth	Geology	Geology at bottom	Daily amts. oil, gas, water	Remarks	6-1-49
Freeman & Nelson White Oil Co.	1 4-3-15	1899	Td 520	All wells started in Placerita metasedimentary rocks and Rubio diorite gneiss near the Placerita fault, and bottomed in same formations			2½ B/D	Aband.
Freeman & Nelson White Oil Co.	2 4-3-15	1900	Td 1030				Trace	Aband.
Freeman & Nelson White Oil Co.	3 4-3-15	?	Td 457				Trace	Aband.
New Century Oil Co.	1 4-3-15	1900-01	Td 720				"Several" 43°	Aband.
New Century Oil Co.	2 4-3-15	1900-01	Td 700				Traces	Aband.
New Century Oil Co.	3 4-3-15	1901?	Td 900				Dry	Aband.
New Century Oil Co.	4 4-3-15	1901?	Td 1000				Small show white oil	Aband.
Pioneer White Oil Co.	1 3-3-15	1901	Td 1270				Very little white oil; gas	Aband.
San Miguel Oil & Development Co.	1 3-3-15	1902	Td 1000				Traces white oil	Aband.
Harrison Well	1 3-3-15	1905	Td 2100				Dry	Aband.
Los Angeles & Kern Co. Oil Mining Co.	1 4-3-15	1912	Td 450+				Unknown results	

Table 5. Wells drilled in Whitney Canyon area *

Operator	Well S-T-R	Yr. comp. or aband.	Depth	Geology	Geology at bottom	Daily amts. oil, gas, water	Remarks	Status † 6-1-49
Republic Petroleum Co., Ltd. (Operator in 1934)	Banner 1 6-3-15	1917-18	2117	Tsr? Tp? Oil sd 1030-1175 Eo. at 1225?	Eo.?	25 B/D 15° 50%	Showings light oil between 1380-2117. Prod. at 911?	Aband.
	Banner 2 6-3-15	1919-20	1692				Never produced	Aband.
	Banner 3 6-3-15	1893	850	Top oil sd. 750		100 B/D?	Discovery well. No water shut-off.	Aband.
	Golden West 1 6-3-15	1894	930			250 B/D?	Water broke in; could not shut off.	Aband.
	Fink 1 7-3-15	1899-1900	1450		Eo.?	? 40°	Light green oil; prod. declined rapidly.	Aband.
	Fink 2 7-3-15	1900	1000				Never produced	Aband.
	Kellerman 3 7-3-15	?	?				No record	Aband.
	Price 1 6-3-15	1908	950			? 17°	Prod. brownish-green oil from below 835.	Aband.
	Price 2 6-3-15	1908?	1100	Heavy oil sd. 600. Second sd. 1000+.			Could not shut off water.	Aband.
	Price 3 6-3-15	1909?	650 ±	Heavy oil sd. over 600.		?		Aband.
	Price 4 6-3-15	1930-33	2842		Middle Eo.	2 B/D 26° 5 B/D water	Pliocene-Eocene contact 1174	Aband.
	Tunnel 1 6-3-15	1916-17	1548	Oil sd. 1038-1418 Tsr.? Tp.?		25 B/D 14° 83%		Aband.
	Yankee Doodle 1 6-3-15	1900	705				Some oil reported	Aband.

Table 6. Wells drilled in Placerita Canyon area since 1934
(April 1948 to June 1949)

Operator	Well S-T-R	Yr. and mon. comp. or aband.	Depth—total producing	Geology	Geology at bottom	Daily amts. oil, gas, & water	Remarks	Status 6-1-49
Standard Oil Company	Placerita 1 [1] 6-3-15	7–48	820 TD 820 Perf. int. 652-820	Qs-Tsr (?) to 215 (?) Tp 215-821	Tp	21 B/D 12.9° 1 M/D est. 1 B/D	Top Pico contact est. from elec. log only in wells 1-7	Prod.
Standard Oil Company	Placerita 2 [1] 6-3-15	8–48	1400 TD 1150 Perf. int. 993-1140	Qs-Tsr (?) to 495 (?) Tp 495-1385 Eo. 1385-1400 (?)	Eo.	11 B/D 12.9° 1 M/D est. 2 B/D	No core or ditch samples of Eocene	Prod.
Standard Oil Company	Placerita 3 [1] 6-3-15	8–48	1061 TD 740 Perf. int. 509-731	Qs-Tsr (?) to 125 (?) Tp 125-870. Eo. 870-1061	Eo.	25 B/D 15.1° 1 M/D est. 53 B/D	Cored Eocene 1050-61	Prod.
Standard Oil Company	Placerita 4 [1] 6-3-15	9–48	1051 TD 1051 Perf. int. 775-1051	Qs-Tsr (?) to 395 (?) Tp 395-1046	Tp	31 B/D 12.6 1 M/D est. 2 B/D		Prod.
Standard Oil Company	Placerita 5 [1] 6-3-15	12–48	1380 TD 1380 Perf. int. 1114-1378	Qs-Tsr (?) to 845 (?) Tp 845-1370	Tp	116 B/D 11.9 4 M/D est. 3 B/D		Prod.
Standard Oil Company	Placerita 6 [1] 6-3-15	12-48	650 TD 650 Perf. int. 297-648	Qs-Tsr (?) to 100 (?) Tp 100-653	Tp	24 B/D 15.5 10/M/D est. 152 B/D		Prod.
Standard Oil Company	Placerita 7 [1] 6-3-15	1-49	1460	Qs-Tsr (?) to 925 (?) Tp 925-1460	Tp			Prod.
Algord Oil Company	Shepard 5 1-3-16	10-48	TD 1225				Dry	Aband.

Table 6. Wells drilled in Placerita Canyon area since 1934—Continued
(April 1948 to June 1949)

Operator	Well S-T-R	Yr. and mon. comp. or aband.	Depth—total producing	Geology	Geology at bottom	Daily amts. oil, gas, & water	Remarks	Status 6-1-49
W. Y. Lee	Heil 1 32-4-15	5-49	TD 1435				Dry	Aband.
W. J. Carter	Carter-Earl 1 5-3-15	9-48	TD 205		"Granite"		Dry	Aband.
W. J. Carter	Carter-Earl 2 5-3-15	10-48	TD 653		"Granite"		Dry	Aband.
W. J. Carter	Carter-Earl 3 5-3-15	9-48	TD 1038		"Granite"		Dry	Aband.
W. J. Carter	Carter-Earl 4 5-3-15	2-49	TD 1248				Dry	Aband.
Republic Petroleum Co.	Price 5 6-3-15	5-35	TD 1080					Aband.
Republic Petroleum Co.	Wm. G. McAdoo, Jr. 1 6-3-15	7-37	TD 835?					Aband.
Crawford & Hiles	Aqueduct 1 6-3-15	12-48	TD 1395					Prod.
Crawford & Hiles	Aqueduct 2 6-3-15	1-49						Prod.
M-C Oil Co.	Dudley 1 6-3-15	10-48						Prod.
M-C Oil Co.	Dudley 2 6-3-15	11-48						Prod.
M-C Oil Co.	Dudley 3 6-3-15	4-49						Prod.
Guiberson Oil Company	Shepard 1 1-3-16							Drilling
Guiberson Oil Company	Shepard 5 1-3-16							Drilling
Guiberson Oil Company	Shepard 5A 1-3-16							Drilling
Guiberson Oil Company	Schisler 1 1-3-16	3-49						Prod.
Guiberson Oil Company	Schisler 2 1-3-16	4-49						Prod.

Guiberson Oil Company	Schisler 3 1-3-16	5-49						Prod.
Guiberson Oil Company	Schisler 4 1-3-16	2-49						Prod.
Guiberson Oil Company	Schisler 5 1-3-16	3-49						Prod.
Guiberson Oil Company	Schisler 6 1-3-16							Drilling
Guiberson Oil Company	Schisler 7 1-3-16	3-49						Prod.
Ramon Somavia	Juanita 1 31-4-15	1-49	Prod. 1830 TD 1835	Wells in this section producing from Upper Pico fm. at depths of 1300-2100		340 B/D 22.4° 3%	First flowing well; also highest gravity	Prod.
Ramon Somavia	Juanita 2 31-4-15	5-49	TD 1942			720 B/D 23° 0.5%		Prod.
Ramon Somavia	Ashley 1 31-4-15		TD 1976			1000 B/D 21°		Prod.
Ramon Somavia	Ashley 2 31-4-15							Drilling
Ramon Somavia	Jean 1 31-4-15							Drilling
Ramon Somavia	Jean 2 31-4-15	4-49				430 B/D		Prod.
Trical Oil Co.	Fehsel 1 31-4-15							Drilling
Rothschild Co.	Rassp Comm. 1 31-4-15							Drilling
Rothschild Co.	Rassp Comm. 2 31-4-15							Drilling
Rothschild Co.	Rassp 1 31-4-15	5-49				400 B/D 22.5°		Prod.
Rothschild Co.	Cole Comm. 1 31-4-15							Drilling
Rothschild Co.	Boyd Comm. 1							Drilling
General Petroleum Corp.	Orwig 1 31-4-15	4-49				210 B/D 22°	Flowing	Prod.
Gordon Oil Co.	Peggy Moore 2 31-4-15	5-49						Prod.
Gordon Oil Co.	Peggy Moore 3 31-4-15	5-49						Drilling

Table 6. Wells drilled in Placerita Canyon area since 1934—Continued
(April 1948 to June 1949)

Operator	Well S-T-R	Yr. and mon. comp. or aband.	Depth—total producing	Geology	Geology at bottom	Daily amts. oil, gas, & water	Remarks	Status 6-1-49
Nelson-Phillips Oil Co.	Kraft 1 31-4-15	4-48	TD 2242 Perf. 580-714	Qs to 420 Tsr-Tpu oil sand 130 ft. thick	Eo. hard ss-sh	60 B/D 16° 5%	Discovery well	Prod.
Nelson-Phillips Oil Co.	Kraft 2 31-4-15	6-48	TD 782			80 B/D 16° 1%		Prod.
Nelson-Phillips Oil Co.	Kraft 3 31-4-15	7-48				100 B/D 16° 2%		Prod.
Nelson-Phillips Oil Co.	Kraft 4 31-4-15	9-48				50 B/D 15°		Prod.
Nelson-Phillips Oil Co.	Kraft 5 31-4-15	11-48	Prod. 605			35 B/D		Prod.
Nelson-Phillips Oil Co.	Kraft 6 31-4-15	10-48						Prod.
Nelson-Phillips Oil Co.	Kraft 7 31-4-15	1-49						Prod.
Nelson-Phillips Oil Co.	Kraft 8 31-4-15	2-49						Prod.
Nelson-Phillips Oil Co.	Kraft 9 31-4-15	2-49						Prod.
Nelson-Phillips Oil Co.	Kraft 10 31-4-15							Drilling
Myers & Wilhite	Swall-Ferrier 1 31-4-15	2-49	TD 652					Aband.
Nelson-Phillips Oil Co.	Swall-Ferrier 1 31-4-15	6-48	TD 500				Salt water	Aband.
Nelson-Phillips Oil Co.	Swall-Ferrier 3 31-4-15	11-48	TD 842					Aband.
Indian Oil Company	Wanda Kraft 1 31-4-15	6-48						Prod.

Indian Oil Company	Wanda Kraft 2 31-4-15	8-48	TD 840			80 B/D		Prod.
Indian Oil Company	Wanda Kraft 3 31-4-15	4-49						Prod.
Indian Oil Company	Wanda Kraft 4 31-4-15	11-48						Prod.
Indian Oil Company	Placerita 1 31-4-15	9-48						Prod.
Indian Oil Company	Placerita 2 31-4-15	3-49						Prod.
Spinel Oil Company	K. D. 1 31-4-15	11-48						Prod.
Crawford & Hiles	Newhall Highway 1 31-4-15	7-48	TD 946			75 B/D 12°		Prod.
Crawford & Hiles	Newhall Highway 2 21-4-15	9-48						Prod.
Crawford & Hiles	Newhall Highway 3 31-4-15	11-48						Prod.
Rothschild Company	Placerita Comm. 1 31-4-15	6-49	TD 1836			402 B/D		Prod.
Rothschild Company	Placerita Comm. 2 31-4-15							Drilling
Rothschild Company	Placerita Comm. 3 31-4-15							Drilling
Independent Exploration Company	Newhall Royal Comm. 1 30-4-15	6-49	TD 2037	Top oil sd. at depth approx. 2000 ft. (150 ft. below sea level) 100 ft. oil sd.		725 B/D 23°	N. limit of prod. to date. First prod. on sec. 30	Prod.
King Oil and Gas Co.	Peggy Moore 1 31-4-15	2-49						Prod.
King Oil and Gas Co.	Peggy Moore 2 31-4-15	3-49				100 B/D 16°		Prod.

Table 6. Wells drilled in Placerita Canyon area since 1934—Continued
(April 1948 to June 1949)

Operator	Well S-T-R	Yr. and mon. comp. or aband.	Depth—total producing	Geology	Geology at bottom	Daily amts. oil, gas, & water	Remarks	Status 6-1-49
King Oil and Gas Co.	Peggy Moore 3 31-4-15	3-49						Prod.
King Oil and Gas Co.	Peggy Moore 4 31-4-15	3-49						Prod.
Gordon Oil Co.	Wickman-Ferrier 1 31-4-15	5-49						Prod.
Gordon Oil Co.	Wickman-Ferrier 2 31-4-15	6-49						Prod.
Gordon Oil Co.	Wickman-Ferrier 3 31-4-15							Drilling
Gordon Oil Co.	Wickman-Ferrier 4 31-4-15							Drilling
Newhall Refining Co.	Philbert 1 31-4-15	9-48	TD 1400			30 B/D 15° 1%	On gas lift	Prod.
Newhall Refining Co.	Philbert 2 31-4-15	2-49						Prod.
General Petroleum Corp.	Castruccio 1 31-4-15	1-49	TD 1460 Prod. 1240-1460	Qs-Tsr (?) top to bottom	Tsr (?)	80-90 B/D 12° 9%	Some oil between 1005-1160	Prod.
General Petroleum Corp.	Castruccio 2 31-4-15	2-49						Prod.
General Petroleum Corp.	Castruccio 3 31-4-15	2-49						Prod.
General Petroleum Corp.	Castruccio 7 31-4-15	3-49						Prod.

Newhall Refining Co.	Philbert Comm. 1-1 31-4-15	7-48						Prod.
Newhall Refining Co.	Philbert Comm. 3-1 31-4-15	11-48						Prod.
Richfield Oil Corp.	Shepard 1 1-3-16							Aband.
Bettymac Oil	Warren 1 1-3-16							Drilling
York Oil Co.	York 5 36-4-16	Comp. 36 Aband. 43	TD 2735					Aband.
B. B. Breckenridge	Atomic 1 36-4-16	12-48						Prod.
B. B. Breckenridge	Atomic 2 36-4-16	1-49						Prod.
George Terry Drilling Co.	Breckenridge 1 36-4-16	3-49						Prod.
George Terry Drilling Co.	Breckenridge 2 36-4-16	4-49	TD 1596			25 B/D 12.8° 10%		Prod.
George Terry Drilling Co.	Breckenridge 3 36-4-16							Drilling
Federal Oil Co.	Oakgrove 1 36-4-16	1-49						Aband.
Ned Barmore	Hays 1 36-4-16	8-48	TD 2387				No showings	Aband.
Terminal-McBurney	Thompson 1 36-4-16		TD 2524 in April		Being deepened to test Eo.		Aband. in April; being deepened in June	Drilling
Crawford & Hiles	Placerita 1 32-4-15	6-49	TD 3307 Prod. 1695			1000 B/D 22°		Prod.

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* Based on data from Walling, R. N., Report on Newhall oil field: California Div. Oil and Gas, Summary of Operations, vol. 20, no. 2, table 9, p. 49, table 10, p. 53, pl. 4, 1934.

† All wells abandoned by 1937.

[1] Based on data supplied by Standard Oil Co.

PERLITE DEPOSITS IN SONOMA COUNTY, CALIFORNIA

By Charles W. Chesterman [*]

It is within the past few years that perlite has graduated from a rock known only to the geologist to a raw material widely known to many prospectors and others interested in lightweight aggregates. This new raw material has become increasingly more popular owing to the fact that on quick heating to softening temperature, it will expand into a pumice-like product which has desirable properties of a lightweight aggregate.

Deposits, from which may be obtained perlite suitable for making lightweight aggregates for use in plaster and concrete, occur in several places in Sonoma County. Most of these deposits are associated with rhyolite and rhyolitic tuffs of the Sonoma volcanics which outcrop extensively in the southeastern part of the county.

The perlite is a volcanic glass like obsidian. However, instead of being glassy clear like obsidian, it is characterized by numerous concentric cracks which, upon weathering and crushing, give rise to pearl-shaped fragments. The perlite in many places contains small phenocrysts or crystals of quartz, orthoclase, plagioclase, and biotite which may constitute as much as 10 percent of the rock. It varies in color from light gray to dark gray, and in places it has a mottled appearance caused by the irregular distribution of numerous minute flakes of red hematite.

The usual mode of occurrence of perlite is as flows, oftentimes associated with rhyolite flows, or as lenticular bodies enclosed within thick beds of rhyolitic tuff.

At the A. W. Frazier property in secs. 1 and 11, T. 6 N., R. 6 W., M.D., about 4 miles northeast of Glen Ellen and State Highway 12, the perlite occurs as lenticular bodies in rhyolitic tuffs and as flows. The perlite flows are underlain by a silicified rhyolitic tuff and are overlain by riebeckite rhyolite. The riebeckite rhyolite is, however, being quarried for flagstone and building blocks at the Valley of the Moon quarry 1.5 miles northeast of Glen Ellen. The perlite is light gray in color and has a well-developed perlitic structure. It is brecciated in places and contains in the upper part of many of the bodies spherulites of radiating fibers of quartz and potash feldspar and lithophysae more or less filled with quartz, chalcedony, opal, and clay.

On the Annadel Farms, which are owned by J. J. Cooney, there occur two distinct types of perlite: one containing rounded fragments of black, glassy obsidian; and the other, more or less devoid of quartz and feldspar crystals, containing no obsidian. Those bodies of perlite which contain the obsidian are well exposed in two small quarries opened for road metal on the abandoned railroad right-of-way 3 miles northwest of Lawndale. This perlite is light gray in color. It occurs as lenticular bodies of variable thickness and length in a platy rhyolite whose flow banding and prominent jointing strike north and dip steeply east. The perlite in places is highly brecciated and contains, besides rounded fragments of black obsidian, considerable clay which was formed through alteration of the perlite.

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[*] Associate Geologist, California State Division of Mines. Manuscript submitted for publication August 1, 1949.

The second type of perlite that occurs on the Annadel Farms is well exposed at the Gordenecker flagstone quarry where it overlies rhyolite which is quarried for flagstone and building blocks.

The perlite occurs as a flow of variable thickness that dips at a comparatively low angle toward the east. It is dark gray in color and more or less devoid of quartz and feldspar, as well as spherulites and lithophysae.

A large deposit of perlite occurs in the NE¼ sec. 7, T. 6 N., R. 7 W., M.D., about three-quarters of a mile north of the Steuben School on property owned by C. M. K. Quinlan of Santa Rosa. The perlite is rhyolite in composition, light gray in color, and contains noticeable amounts of quartz, feldspar, and biotite. It forms a flow of variable thickness and length and overlies rhyolite tuffs which, in turn, are overlain and underlain by flows of dark gray, platy, massive andesite.

Although there has been no production of perlite from any of the deposits in Sonoma County, they seem to contain large volumes of material suitable for the manufacture of lightweight aggregate. Besides being large, the deposits are easily accessible and comparatively close to the San Francisco Bay area, one of the more important marketing centers on the Pacific Coast.

MINES AND MINERAL RESOURCES OF SONOMA COUNTY, CALIFORNIA

By Martin T. Honke Jr.* and William E. Ver Planck Jr.*

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ABSTRACT

Sonoma County, one of the original 27 counties formed in 1850, borders the Pacific Ocean north of San Francisco Bay. It has an area of 1579 square miles and is primarily agricultural. Cities, in addition to Santa Rosa, the county seat, include Petaluma, Healdsburg, Sebastopol, and Sonoma.

Sonoma County ranked thirtieth among the counties of California in the value of mineral products produced in 1946. The total recorded value of mineral production at the end of 1947 was $22,620,050. Of this amount, sand and gravel and stone products have accounted for $12,489,255, quicksilver for $5,843,978.

Sandstones of the Franciscan group outcrop over the greater part of the county. Pliocene sediments occur in the southern part, and the Pliocene Sonoma volcanics cover a large area in the eastern half of the county.

Common brick was made from red burning clay at Glen Ellen, Guerneville, and Santa Rosa before 1902. A kaolin fire clay has been mined near Glen Ellen. Small deposits of chromite are associated with serpentine in the Franciscan areas. About 1000 tons of chromite were mined during World War I, and about 100 tons during World War II. Four occurrences of coal have been reported, and some lignite was mined prior to 1890. A few tons of copper were mined prior to 1880 from serpentine contacts. Deposits of diatomite are associated with the Sonoma volcanics, and there has been a small production of diatomite from the vicinity of Glen Ellen. Two small low-grade graphite deposits were mined 50 years ago. Limestone deposits are known but have been worked to only a limited extent. Magnesite deposits are small and unable to compete with sea-water magnesite; however, 26,000 tons were mined before

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* Junior Mining Geologist, California State Division of Mines. Manuscript submitted for publication August 1, 1949.

1921. Deposits of manganese oxide are associated with the cherts of the Franciscan group. Total production is about 1500 tons. Undeveloped perlite deposits exist in the east central part of the county. A shallow well in the Petaluma formation east of Petaluma produced a few barrels of petroleum during 1948.

Quicksilver production began probably in 1861 and has closely followed the fluctuations of quicksilver prices. Most of the production has come from the Contact, Socrates, Culver-Baer, and Cloverdale mines in the Western Mayacmas district and the Great Eastern and Mount Jackson mines in the Guerneville district.

Sand and gravel is obtained from the Russian River, Santa Rosa Creek, and Sonoma Creek. Crushed and broken stone is obtained in large part from the Sonoma volcanics. Production of these stone products was first recorded in 1887. "Flagstones" and colored building stone are quarried from the Sonoma volcanics near Glen Ellen for a limited local market.

INTRODUCTION[1]

Sonoma is an Indian word which means ''Valley of the Moon.'' The Indians of the tribe that inhabited the valley were called Chocuyens. Indians, Russians, and Spaniards preceded the American settlers in this area. Sonoma is one of the original 27 counties formed in February 1850.

Geography

Sonoma County is bordered on the west by the Pacific Ocean, on the north by Mendocino County, on the east by Lake County and Napa County, and on the south by a portion of San Pablo Bay and the northern edge of Marin County. The county is 40 to 50 miles long in the north-south direction, 30 to 40 miles wide in the east-west direction, and has a total area of 1579 square miles. Santa Rosa, the county seat, is about 45 miles north of San Francisco by U. S. Highway 101.

The Southern Pacific, Northwestern Pacific, and the Petaluma and Santa Rosa railroads serve various communities in southern Sonoma County. U. S. Highway 101 crosses the county in a north-south direction. State Highways 1, 12, 28, 37, and 48, also the county roads, make points in this county accessible. Petaluma Creek provides small vessel service as far north as Petaluma. Bus and truck lines serve the entire area.

The population in 1940 was 69,052 and was classed as 33.5 percent urban and 66.5 percent rural. The estimated population of the county in January 1946 was 85,200, which is an increase of 23 percent since the 1940 census. The five urban centers are Santa Rosa, Petaluma, Healdsburg, Sebastopol, and Sonoma.

The climate of Sonoma County is pleasant and is without extremes in temperature or rainfall. The rainfall varies from 50 inches along the coast to 29 inches in the south-central part of the county; a maximum of 60 inches is reached on Mount St. Helena. A rainy season occurs from November to April, and the summers are dry. The growing season is approximately 207 days in length; killing frosts are rare. At Santa Rosa the average temperature is 46.4° Fahrenheit in January and 65.6° Fahrenheit in July.

Topography. Elevations in Sonoma County range from sea level to 4262 feet on the eastern edge of the county at Mount St. Helena. The county is located in the Coast Ranges, and includes areas of level valleys, low rolling hills, and rugged mountains with high relief. A main valley area narrows as it extends northward about 60 miles from San Pablo Bay and is 10 to 25 miles wide. This valley is called Petaluma in the south, Santa Rosa in the center, and Russian River valley in the north. The valleys of Sonoma County are separated by spurs of the main ridge. Sonoma Valley, from which the county takes its name, is a very small portion of the county.

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[1] Thompson, R. A., Historical and descriptive sketch of Sonoma County, California, pp. 8-22, 1879.
California Blue Book, California State Dept. Finance, pp. 729-732, Sacramento, 1946.

The northern two-thirds of the county is drained by the Russian River into the Pacific Ocean; the southern one-third is drained into San Pablo Bay by Sonoma Creek and Petaluma Creek.

Topographic maps on a scale of 1:62,500, or about 1 inch to 1 mile, are available for the entire county. The following quadrangles of the United States Geological Survey cover parts of the county: Lower Lake, Healdsburg, Santa Rosa, Sebastopol, Mare Island, Petaluma, and Point Reyes. The rest of the county is covered by quadrangles of the Corps of Engineers, United States Army, comprising Point Arena, Ornbaun, Hopland, Kelseyville, Plantation, Skaggs, Duncan Mills, and Sonoma. In addition, the United States Geological Survey has published these quadrangles on the scale of 1:31,680 or about 2 inches to the mile: Stewarts Point, Annapolis, Tombs Creek, Skaggs Springs, Plantation, Fort Ross, Cazadero, Arched Rock, Duncan Mills, and Bodega Head.

Industries. The principal industry in Sonoma County is agriculture, the products from which were valued at $60,081,686 in 1944. Poultry and dairy products, beef cattle and other animals, orchard and field crops contributed to this total. The county has meat and poultry packing plants, wineries, fruit canneries, fruit drying plants, and milk processing plants.

The total value of all minerals produced in 1947 in this county was $1,050,051, mainly from sand, gravel, crushed stone, and quicksilver.

Geology

The geology of much of Sonoma County has not been described, but reports covering scattered sections are available or in press.[2]

The oldest formation in Sonoma County is the Bodega diorite which forms a small outcrop west of the San Andreas fault on Bodega Head. It is the northern tip of a large body of such rock which occurs on the Point Reyes Peninsula in Marin County.

The Franciscan group, probably of late Jurassic age, outcrops over most of the northern half of the county. West of Santa Rosa Valley in the southern half of the county the Franciscan is in large part concealed by a thin cover of Tertiary sediments. The Franciscan is predominately massive arkosic sandstone interbedded with a minor amount of dark fissile shale and conglomerate. Lenticular bodies of radiolarian chert are a characteristic feature. Associated with the Franciscan are altered

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[2] Bailey, E. H., Quicksilver deposits of the western Mayacmas district, Sonoma County, California: California Div. Mines Rept. 42, pp. 199-230, 1946. (Portions of the Calistoga, Healdsburg, and Kelseyville quadrangles in Sonoma County.)

Myers, W. B., and Everhart, D. L., Quicksilver deposits in the Guerneville district, Sonoma County, California: California Jour. Mines and Geology, vol. 44, pp. 253-277, 1948.

Johnson, F. A., Petaluma region: California Div. Mines Bull. 118, pp. 622-627, 1943. (Portions of the Duncan Mills, Sebastopol, Fort Ross, Cazadero, Santa Rosa, and Petaluma quadrangles in Sonoma County.)

Weaver, C. E., Geology and mineral deposits of an area north of San Francisco Bay: California Div. Mines Bull. 149 (in press). (Includes the Santa Rosa, Sonoma, Petaluma, and Mare Island quadrangles.)

Table 1. Mineral production of Sonoma County, 1873-1947.

Year	Quicksilver		Mineral paint		Brick		Mineral water		Miscellaneous stone, [1] value	Magnesite		Miscellaneous and unapportioned		
	Flasks	Value	Tons	Value	M	Value	Gallons	Value		Tons	Value	Amount	Value	Substance
1873	50	$4,017	------	------	------	------	------	------	[6]	------	------	------	------	
1874	1,700	178,806	------	------	------	------	------	------	------	------	------	------	------	
1875	1,218	102,495	------	------	------	------	------	------	------	------	------	------	------	
1876	3,897	171,468	------	------	------	------	------	------	------	------	------	------	------	
1877	3,609	134,616	------	------	------	------	------	------	------	------	------	------	------	
1878	3,255	106,890	------	------	------	------	------	------	------	------	------	------	------	
1879	2,977	88,923	------	------	------	------	------	------	------	------	------	------	------	
1880	1,445	44,795	------	------	------	------	------	------	------	------	------	------	------	
1881	1,273	37,974	------	------	------	------	------	------	------	------	------	------	------	
1882	2,124	59,960	------	------	------	------	------	------	------	------	------	------	------	
1883	1,669	47,984	------	------	------	------	------	------	------	------	------	------	------	
1884	332	10,126	------	------	------	------	------	------	------	------	------	------	------	
1885	446	13,715	------	------	------	------	------	------	------	------	------	------	------	
1886	735	26,093	------	------	------	------	------	------	------	------	------	------	------	
1887	689	29,196	------	------	1,000	$5,000	------	------	$350,000	------	------	------	------	
1888	1,151	48,918	------	------	1,000	5,000	------	------	367,500	------	------	------	------	
1889	1,345	60,525	------	------	------	------	------	------	[2] 297,236	------	------	------	------	
1890	1,046	54,915	------	------	------	------	------	------	[3] 245,000	------	------	------	------	
1891	1,660	75,115	------	------	------	------	------	------	[3] 150,000	------	------	------	------	
1892	1,630	66,357	------	------	------	------	------	------	96,000	------	------	------	------	
1893	1,445	53,104	------	------	------	------	------	------	92,800	------	------	------	------	
1894	1,368	41,998	100	$3,500	375	1,875	------	------	57,381	------	------	------	------	
1895	1,813	70,707	225	3,375	350	1,750	8,000	$32,500	69,508	------	------	------	------	
1896	1,126	37,150	220	3,740	250	1,250	14,400	19,287	73,719	------	------	------	------	
1897	1,538	59,982	270	3,780	[3] 300	1,500	236,000	24,000	33,035	------	------	------	------	
1898	1,704	63,048	------	------	350	2,800	246,680	23,490	43,371	------	------	------	------	
1899	2,119	105,950	------	------	200	1,800	21,000	18,500	16,830	------	------	------	------	
1900	2,209	99,500	------	------	280	2,360	575,000	35,000	20,275	------	------	------	------	
1901	2,130	95,850	------	------	150	1,200	60,900	17,691	52,701	175	$1,225	64 tons	$4,460	Graphite.
1902	1,440	64,685	30	105	150	1,200	30,000	9,100	121,578	130	455	42 tons	1,680	Graphite.
1903	2,404	98,676	800	320	160	1,440	10,000	4,000	90,933	------	------	------	------	
1904	[4] 2,700	102,829	------	------	175	1,750	11,000	4,400	75,947	------	------	1,500 bbls.	2,250	Lime.
1905	2,504	97,041	------	------	500	4,000	10,000	4,000	213,830	------	------	------	------	
1906	2,070	75,555	------	------	6,800	115,000	10,000	4,000	158,218	------	------	------	300	Gems.

1907	560	21,369	--------	--------	11,600	133,479	12,000	4,200	132,946	250	1,250	1,500 bbls.	2,600	Lime.
												----------	50	Gems.
												10,500 tons	10,700	Clay.
1908	590	24,939	--------	--------	11,000	83,000	10,000	1,000	307,695	15	180	2,600 tons	3,000	Clay.
1909	344	14,226	--------	--------	6,500	29,000	104,000	21,350	319,716	--------	--------	500 tons	5,500	Clay.
												----------	15,000	Unapportioned, 1900-09.
1910	260	11,765	--------	--------	--------	--------	235,000	50,350	220,998	--------	--------	----------	--------	
1911	94	4,325	--------	--------	--------	--------	202,500	50,250	184,035	--------	--------	----------	1,000	Unapportioned.
1912	646	27,158	--------	--------	--------	--------	62,500	20,950	295,198	300	3,000	----------	--------	
1913	12	483	--------	--------	--------	--------	96,240	46,910	191,436	--------	--------	----------	--------	
1914	13	638	--------	--------	--------	--------	80,015	46,160	276,516	213	2,130	----------	700	Other minerals.
1915	159	21,793	--------	--------	--------	--------	258,600	41,231	177,917	3,624	34,788	----------	375	Other minerals.
1916	1,039	97,140	--------	--------	--------	--------	121,366	28,031	232,113	11,653	98,280	243 tons	2,478	Chromite.
												----------	14,000	Building stone, manganese.
1917	2,592	24,481	--------	--------	--------	--------	121,290	35,031	146,621	5,636	61,335	226 tons	6,200	Chromite.
												362 tons	12,689	Manganese.
												----------	64	Other minerals.
1918	2,417	28,223	--------	--------	--------	--------	83,220	36,050	148,347	4,110	40,010	1,540 tons	73,906	Chromite.
												173 tons	7,645	Manganese.
												----------	100	Other minerals.
1919	1,418	119,142	--------	--------	--------	--------	96,800	22,820	144,014	--------	--------	----------	62	Building stone, curbing.
1920	[5]	--------	--------	--------	--------	--------	29,928	6,578	217,667	[5]	--------	----------	63,000	Magnesite, quicksilver.
1921	[5]	--------	--------	--------	--------	--------	37,641	9,891	151,300	[5]	--------	----------	14,360	Gems, magnesite, quicksilver.
1922	[5]	--------	--------	--------	--------	--------	35,843	9,108	162,679	--------	--------	----------	50,154	Pottery clay, gems, quicksilver.
1923	528	31,147	--------	--------	--------	--------	30,661	7,106	189,059	--------	--------	----------	--------	
1924	867	60,840	--------	--------	--------	--------	31,003	8,002	101,009	--------	--------	----------	2,200	
1925	351	29,134	--------	--------	--------	--------	17,713	6,679	119,546	--------	--------	----------	4,872	Pottery clay, building stone, manganese.
1926	[5]	--------	--------	--------	--------	--------	36,272	7,752	208,479	--------	--------	----------	6,355	Pottery clay, gems, manganese ore, petroleum, quicksilver.
1927	373	43,068	--------	--------	--------	--------	25,428	5,889	208,753	--------	--------	----------	7,682	Petroleum, sandstone.
1928	[5]	--------	--------	--------	--------	--------	32,720	9,127	111,429	--------	--------	----------	6,250	Sandstone.
												----------	85,763	Chromite, gems, quicksilver.
1929	[5]	--------	--------	--------	--------	--------	20,701	7,376	243,383	--------	--------	----------	13,351	Sandstone.
												----------	87,208	Chromite, gems, quicksilver.
1930	[5]	--------	--------	--------	--------	--------	17,900	5,318	263,644	--------	--------	----------	61,437	Quicksilver, sandstone.
1931	449	39,392	--------	--------	--------	--------	44,576	8,227	204,702	--------	--------	----------	315	Unapportioned.
1932	247	11,642	--------	--------	--------	--------	15,864	4,123	151,734	--------	--------	----------	350	Unapportioned.
1933	[5]	--------	--------	--------	--------	--------	23,016	2,390	147,266	--------	--------	----------	8,332	Tuff, quicksilver.
1934	393	27,288	--------	--------	--------	--------	12,944	2,786	130,616	--------	--------	----------	1,375	Unapportioned.
1935	110	7,845	--------	--------	--------	--------	24,474	4,295	146,963	--------	--------	----------	11,380	Volcanic rock.
													317	Gold.
1936	182	14,081	--------	--------	--------	--------	29,642	6,460	160,068	--------	--------	----------	4,808	Pottery clay, gems, tuff.

Table 1. Mineral production of Sonoma County, 1873-1947—Continued

Year	Quicksilver		Mineral paint		Brick		Mineral water		Miscellaneous stone,[1] value	Magnesite		Miscellaneous and unapportioned		
	Flasks	Value	Tons	Value	M	Value	Gallons	Value		Tons	Value	Amount	Value	Substance
1937	281	$22,085	--------	--------	--------	--------	[5]	--------	$235,585	--------	--------	--------	$15,393	Pottery clay, tuff, lime, mineral water, sandstone.
1938	425	29,641	--------	--------	--------	--------	23,604	$4,365	[5]	--------	--------	--------	198,489	Pottery clay, tuff, miscellaneous stone.
1939	255	27,212	--------	--------	--------	--------	53,860	6,949	284,616	--------	--------	--------	10,292	Pottery clay, tuff.
1940	1,144	188,467	--------	--------	--------	--------	12,028	3,288	229,033	--------	--------	--------	11,972	Other minerals.
1941	3,195	590,263	--------	--------	--------	--------	88,756	12,722	584,421	--------	--------	--------	--------	
1942	4,115	779,930	--------	--------	--------	--------	80,697	16,603	842,512	--------	--------	--------	16,281	Tuff, manganese ore, natural gas.
1943	4,121	761,654	--------	--------	--------	--------	82,189	13,943	737,048	--------	--------	--------	8,669	Chromite, tuff.
1944	[5]	--------	--------	--------	--------	--------	[5]	--------	[5]	--------	--------	--------	905,121	Chromite, tuff, limestone (shells), mineral water, manganese ore, quicksilver, miscellaneous stone.
1945	[5]	--------	--------	--------	--------	--------	[5]	--------	[5]	--------	--------	--------	807,122	Tuff, mineral water, quicksilver, miscellaneous stone.
1946	[5]	--------	--------	--------	--------	--------	[5]	--------	559,922	--------	--------	--------	299,155	Tuff, mineral water, quicksilver.
1947	4,247	355,644	--------	--------	--------	--------	--------	--------	694,407	--------	--------	--------	--------	
Total	[5] 90,248	$5,843,978	1,645	$14,820	41,140	$393,404	[5] $3,523,971	$769,278	$12,489,255	[5] 26,106	$242,653	--------	$2,866,762	

GRAND TOTAL VALUE—$22,620,050

[1] Includes crushed rock, rubble, rip-rap, paving blocks, sand, gravel.
[2] Eleventh Census Report, vol. 10, pt. 3, p. 605.
[3] Estimated.
[4] Flasks of 76½ pounds previous to June, 1904; of 75 pounds thence, through 1927; of 76 pounds since January, 1928.
[5] See under "Unapportioned."
[6] There was a considerable production of paving blocks in Sonoma County in the '70's and '80's, but no available records of annual amounts or values.

extrusives, both flows and tuff, which are known as greenstone. Serpentine in discontinuous elongated bodies occurs in the Franciscan areas.

Cretaceous rocks are known only along the coast northward from Fort Ross. Here sandstones, shales, and conglomerates lie west of the San Andreas fault and are in fault contact with the Franciscan.

The Petaluma formation of Pliocene age outcrops only in the southeastern corner of the county. It is composed largely of clays and some interbedded sandstone. This formation, which is sharply folded, is in fault contact with the Franciscan.

The Sonoma volcanics, also of Pliocene age, lie unconformably on both the Petaluma formation and the Franciscan group. They cover much of the area east of Santa Rosa Valley and cap the higher peaks of the Mayacmas Mountains in the northeastern portion of the county. This formation consists of basalt, tuff, tuff-breccia, andesite, and rhyolite with interbedded fluviatile sandstones and conglomerates.

The Merced formation, which lies in a shallow basin west of Santa Rosa Valley, is in part contemporaneous with the Sonoma volcanics. It consists of gently folded fine-grained sandstone, conglomerate, and clay shale.

MINERAL RESOURCES

A tabulation of mineral production of Sonoma County, 1873-1947, is presented in table 1. The minerals produced in 1947 were quicksilver, sand and gravel, and stone, having a total value of $1,050,051. Building stone, chromite, clay, diatomaceous earth, gems, gold, tuff, graphite, limestone, magnesite, manganese, mineral paint, mineral water, natural gas, paving blocks, and pottery clay have also been produced, at various times. Occurrences of arsenic, coal, sulphur, copper, gypsum, perlite, pyrite, stibnite, iron, zircon, and onyx are also known.

Brick and Clay

Clays of Sonoma County have been used in the past for the manufacture of common red brick and tile. Samples of clay from Agua Caliente, Guerneville, Healdsburg, Mark West Springs, Santa Rosa, and Sonoma may be seen in the California Division of Mines museum. There are no active clay-working plants, although there are, without doubt, clay deposits of potential value in Sonoma County.

Companies that made bricks in Sonoma County prior to 1909 are the Bagley and Nagle Brick Yard, Santa Rosa; California Pottery and Brick Company, Glen Ellen; Healdsburg Brick Company, Healdsburg; Hilton Brickyard, 19 miles northwest of Santa Rosa; and the Sonoma Brick Company, Glen Ellen.

Beltane deposit is located in sec. 2, T. 6 N., R. 6 W., M.D., about 1½ miles east of Beltane Station. The owner is unknown.

Clay from this deposit was tested and described by Dietrich.[3] It has not been developed.

Weise clay pit [4] is located in sec. 3, T. 6 N., R. 6 W., M.D., in Nuns Canyon 0.4 miles east of State Highway 12. The owner is Shirley E. Weise, of Glen Ellen.

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[3] Dietrich, Waldemar F., The clay resources and the ceramic industry of California: California Div. Mines and Mining Bull. 99, pp. 227, 291, 1928.

[4] Dietrich, W. F., op. cit., pp. 227, 228, 262.

The operation, which is currently inactive, has been confined to two pits, each about 200 yards in diameter and exposing 20 to 30 feet of clay. The clay is a white, moderately plastic, kaoline fire clay. Limonite seams spaced at intervals of several inches are characteristic of the exposed faces. At the edges of the pits the clay is earthy in places, and in horses of waste the material contains shots of opal and crumbles easily. The two deposits are well above the bottom of a hollow surrounded by a brittle, white porcelaneous rhyolite which contains very small quartz phenocrysts and breaks with a conchoidal fracture. The clay is probably an alteration product of the rhyolite. A few small precious opals have been found in both the clay and the rhyolite.

In the past the Weise clay pit has produced a considerable tonnage. The clay was used by Gladding, McBean and Company in the manufacture of fire brick, and by the Santa Cruz Portland Cement Company in the manufacture of white cement. Dietrich tested two samples of the clay from this deposit, and the report of Laizure [5] contains analyses of three samples of this clay.

Chromite

The chromite of Sonoma County occurs in the sill-like bodies of serpentinized ultramafic rock which intrude the Franciscan. The known deposits are found in a northwest-striking belt of serpentine in the western part of the county. The deposits appear to be distributed at random among the serpentinized bodies, for no reliable guides to prospecting have been found. Chromite bodies in this area have the form of lenses or pods which, as the result of Coast Range deformation, are usually bounded by faults. High-grade ore consists of massive chromite with a minimum of gangue; low-grade ores are made up of chromite disseminated in serpentine. Chromite float and alluvial deposits have also been mined.

The main production was before 1890. During World War I a little over 1000 tons was mined, but during World War II only about 100 tons, which came from the Laton mine, was produced.

Some of the chromite deposits have been exhausted, and all were idle in 1948. Dow and Thayer [6] credit the reserves of the county to the Laton mine and the Sonoma Chrome, Inc. property.

Baldrini prospect is located in sec. 27, T. 7 N., R. 10 W., M.D., about 1½ miles north of Occidental. The owner is E. L. Baldrini, of Camp Meeker, California.

This property was leased to E. A. Mellersh (deceased) in January 1942. Development was done by bulldozing surface cuts; this revealed some low-grade chromite which had a northwest strike. The country rock is serpentine. No work was done after 1942, and no ore was shipped. The lease expired in 1943.

Barnes mine [7] is in secs. 30, 31, and 32, T. 11 N., R. 10 W., M.D., about 3½ miles southeast of Cloverdale. It is owned by Italian Swiss Colony, Asti, California.

This property has been known also by the names Ardoin, Ferrara, McMahon Ranch, Patentes, Vadum, and Wanderer.

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[5] Laizure, C. McK, Sonoma County: California Min. Bur. Rept. 22, p. 332, 1926.

[6] Dow, D. H., and Thayer, T. P., Geological investigations of chromite in California: California Div. Mines Bull. 134, pt. 2, pp. 26-29, 1946.

[7] Dow and Thayer, op. cit., p. 26.

The last recorded shipment of ore from the Barnes mine was in 1918; so far as is known, no work has been done at the property since that time. Available information indicates that very little ore in place was mined, but that it was collected from surface float or alluvial deposits.

Most of the mining in this area was done before 1900.

Gaver prospect [8] is in sec. 27, T. 7 N., R. 10 W., M.D., about half a mile east of Camp Meeker. It is owned by A. P. Gaver, Petaluma, California.

Some chromite float was found, and a few small stringers were exposed in pits. The last work done on this prospect was in 1918. There is no record of the shipment of ore.

Laton mine [9] is in the NE¼SE¼ sec. 13, T. 9 N., R. 12 W., and the SW¼SW¼ sec. 18, T. 9 N., R. 11 W., M.D., 10½ miles by road north of Cazadero. The owners are A. J. and C. R. Laton, of Cazadero, California.

The area of the property is about 80 acres. Of the six claims which constitute the mine, the Slats, Rattlesnake, and Yellow Streak are the most highly mineralized. The ore of the Yellow Streak claim is in small high-grade lenses, whereas the ore in the other claims is generally low-grade and disseminated. The lenses strike north to northwest, and dip from about 17° to 62° NE. Except where bounded by slickensided joints, the ore grades into the surrounding serpentinized peridotite.

The terrain is very steep and is practically lacking in vegetation and overburden. The road leading to the district is passable, but in need of repair. Improvements consist of a mill, a blacksmith shop, and two cabins. The mill, located on the bank of Austin Creek, has one primary crusher and 10 stamps. Deister tables were used to concentrate the ore. Gasoline engines supply the power, but electric power lines are now within 2 miles of the mine. All mining is done by means of surface benches and trenches.

In 1916 this mine produced about 100 tons of ore, and it has been worked intermittently since that time. During 1945-46 another 100 tons of ore was produced, the concentrates from which averaged 49 percent Cr_2O_3 and 12½ percent iron. The chrome-iron ratio was 2.7. The concentrates were trucked from the mill.

Reserves in 1943 were estimated by Dow and Thayer to be 10,000 to 15,000 tons. Prospecting and development work are now being done on a part-time basis by the owners.

Madeira claim [10] is in sec. 31, T. 9 N., R. 10 W., M.D., about 8 miles north of Guerneville. It is owned by Henry Doelger.

In 1916 George Madeira of Healdsburg mined about 100 tons of chromite from several small lenses. According to early reports,[11] the ore assayed 34 percent Cr_2O_3; there is no record that it was shipped. No further work has been done on this property.

Red Hill claim [12] is in secs. 15 and 22, T. 11 N., R. 9 W., M.D., 20 miles by road east of Cloverdale. The owner is E. A. Truitt, of Healdsburg, California.

This claim also has been known as Culver Baer chrome mine, Juniper Ridge, Key, Lock, and Lock and Key.

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[8] Dow and Thayer, op. cit., p. 26.

[9] Dow and Thayer, op. cit., pp. 26, 27.

[10] Dow and Thayer, op. cit., p. 27.

[11] Bradley, W. W., Huguenin, E., Logan, C. A., Tucker, W. B., and Waring, C. A., Manganese and chromium in California: California Min. Bur. Bull. 76, p. 201, 1918.

[12] Dow and Thayer, op. cit., pp. 27-28.

The last mining was done in 1918 when G. W. Elder of St. Helena produced from an open cut 150 to 200 tons of ore. Early reports [13] state that the grade of the ore was 30 to 40 percent Cr_2O_3.

Rough Crossing claim,[14] also known as Eakles Brothers chrome claim, is in sec. 21, T. 9 N., R. 11 W., M.D., about 6 miles northwest of Armstrong Grove. The owner is unknown.

The last mining on the property was done in 1918, when about 12 tons of 40 percent Cr_2O_3 was mined; no ore was shipped. Since the removal of the 24-inch gauge railroad of the Sonoma Magnesite Company, it is very difficult to get to this property.

Shanks and Copps claim [15] is in sec. 13, T. 10 N., R. 11 W., M.D., 9 miles west of Geyserville. It is owned by E. D. Thompson.

Before 1918 about 20 tons of fairly high grade ore was mined from several small deposits on this property. Float is abundant on the slope of the ridge north of Skaggs Springs. The claim has been idle since 1918.

Sonoma Chrome, Inc., mine [16] is in secs. 15, 16, and 17, T. 7 N., R. 10 W., M.D., 3½ miles north of Occidental. It is owned by Florence M. Button, of Camp Meeker, California.

The ore occurs as small kidneys of chromite which strike about N. 40° W. and are parallel to the schistosity of the serpentine country rock. A shaft 55 feet deep, drifts, pits, and trenches were used to develop this mine. Production came mostly from a large open cut.

In 1918 the property, then called the Meeker mine, was leased to S. H. Dolbear, who mined and shipped 644 long tons of ore containing 39 to 42 percent Cr_2O_3. In 1942 a 2000-acre tract of this land was leased to Bentley Newman of Santa Clara, who, after obtaining a loan from the Reconstruction Finance Corporation, cleaned out the shaft and old chromite workings and repaired the road. Evidentally not enough ore was developed to warrant further work, because on expiration of the lease in 1943, no ore had been mined.

The high-grade ore is said to contain from 42 to 51 per cent Cr_2O_3 with about 3 : 1 ratio of Cr : Fe. Dow and Thayer [17] estimated the reserves to be less than 5000 long tons. The property is idle.

Warner and Clark claim [18] is in sec. 10, T. 10 N., R. 8 W., M.D., 13 miles northeast of Healdsburg. It is owned by Anna Warner, of Pine Flat, California.

Chromite on this property occurs as surface float and as small lenses of high-grade ore in place. There is no record of any ore shipments from this deposit. No activity has been reported in recent years.

Welch prospect [19] is in sec. 22, T. 9 N., R. 11 W., M.D., 5 miles northwest of Armstrong Grove. It is owned by T. G. Sinclair, of Guerneville, California.

The ore occurs as lenses which range from a fraction of an inch to 2 feet in width, strike northwest, and have a vertical dip. Before 1918 a small amount of surface development work was done. Since 1918 no activity has been reported. At present this property is practically inaccessible.

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[13] Caldwell, F. B., Reports on chrome localities in California; made for U. S. Bureau of Mines as part of Cooperative War Minerals Investigation in California, in cooperation with U. S. Geological Survey and California State Council of Defense. Unpublished; on file at offices of California Division of Mines, 1918.

[14] Dow and Thayer, op. cit., p. 28.

[15] Bradley, W. W., et al., op. cit., p. 203.

[16] Dow, D. H., and Thayer, T. P., op. cit., p. 28.

[17] Dow and Thayer, op. cit., p. 29.

[18] Dow and Thayer, op. cit., p. 29.

[19] Caldwell, F. B., op. cit.

Coal

Coal has been located in several places in Sonoma County, but is not being mined. It is generally lignitic and therefore of low rank, and has a high ash content. Occurrences are known in sec. 33, T. 6 N., R. 6 W., M.D. (projected), 2 miles east of Agua Caliente, and SE¼ sec. 19, T. 8 N., R. 12 W., M.D. (projected), a quarter of a mile north of Fort Ross.

Pierson mine is in sec. 27, T. 8 N., R. 8 W., M.D., about 5 miles north of Santa Rosa. It is owned by Wikiup Rancho, Santa Rosa.

In 1910 and 1911 some development work was done, but failed to reveal coal of minable quality; the seam, which is less than 4 feet thick, strikes S. 70° W. and dips 25° NE. No further development work has been done.

Taylor Ranch mine [20] is in the NW¼ sec. 31, T. 7 N., R. 7 W., M.D., 2 miles southeast of Santa Rosa. It is owned by E. M. Weaver, of Santa Rosa, California.

Prior to 1890 approximately 2,000 feet of underground workings were driven; but at the present time all these workings are inaccessible. The State Mineralogist's Report of 1888 states that three seams of lignite were found, underlain by sandstone, and having a hanging wall of fire clay and shale, with sandstone above the shale. It is probable that the strata were too badly broken to be mined economically. These seams strike northwestward and dip toward the southwest.

Copper [21]

The occurrence of copper has been noted in a few places in Sonoma County. Only two of the deposits have been mined, and a few tons of ore were shipped. The prospects form no connected belt, and they offer little hope of proving commercial in extent.

Archer tract [22] is in sec. 30, T. 8 N., R. 9 W., M.D., 1 mile north of Mirabel Park. The owner is unknown.

In 1880 some rich float was found and shipped. Two adits with a total length of 400 feet were driven on a sandstone-serpentine contact, but no vein was found. The mine has been idle since 1910.

Baby Jack and Earl Clare property [23] is located in sec. 3 or 4, T. 9 N., R. 10 W., M.D., about 4 miles northwest of Healdsburg. The owner is unknown.

Several tons of copper were shipped in 1875. A 35-foot adit and a 22-foot shaft explored a quartz vein on the contact of limestone and serpentine. The vein material was stained with copper carbonates, but no copper sulphides were found. This property has been idle since about 1880.

Occurrences.—There are several other occurrences of copper in Sonoma County, among them the Altamont, in sec. 17, T. 7 N., R. 10 W., M.D., 2 miles southeast of Monte Rio; the Cornucopia, in secs. 33, 34, T. 12 N., R. 9 W., M.D., about 4 miles northwest of The Geysers; the Gray prospect, in sec. 26, T. 9 N., R. 12 W., M.D., about 5 miles northwest of Cazadero; the Grizzly, in sec. 5, T. 9 N., R. 12 W., M.D., about

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[20] Irelan, Wm. Jr., Sonoma County: California Min. Bur. Rept. 8, p. 634, 1888.

[21] Aubury, L. E., Copper resources of California: California Min. Bur. Bull. 50, pp. 166-168, 1908.

[22] Aubury, L. E., op. cit., p. 166.

[23] Aubury, L. E., op. cit., pp. 167, 168.

9 miles east of Stewarts Point; the Wall Tract, in sec. 30, T. 8 N., R. 9 W., M.D., 1 mile north of Mirabel Park; and the Ward Tract, in sec. 22, T. 9 N., R. 10 W., M.D., 5 miles west of Healdsburg.

Diatomite

Diatomite is known also as diatomaceous earth, kieselguhr, and infusorial earth. A small amount of diatomite was mined in Sonoma County some years ago, but inasmuch as large deposits in more favorable locations are available, none is being mined there at the present time.

Felder deposit is in sec. 9, T. 5 N., R. 6 W., M.D., 4 miles west of Sonoma. The owner is Leo Felder, Box 248, Sonoma, California.

A few years ago a small tonnage was mined from this deposit, but owing to financial difficulties, the operation ceased. The diatomite, which came from an exposure in a small gully, was white and of pure grade. This deposit appears to contain a large tonnage, though the limits have not been determined. The bed is, at best, 10 feet thick where it is exposed.

Goodman Bros. deposit [24] is in sec. 10, T. 8 N., R. 8 W., M.D., about half a mile north of Mark West Springs. It was owned by Goodman Bros., Santa Rosa, California, in 1926.

The report by Laizure states that this bed averaged about 12 feet in thickness and had been uncovered for 1500 feet. The diatomite is white and apparently of good grade. In 1913 a small tonnage was shipped, but the property has been idle since that time.

Mt. Pisgah Vineyard deposit [25] is in sec. 30, T. 6 N., R. 5 W., M.D., about 2 miles northeast of Agua Caliente. The owner is Louis Martini, St. Helena.

During 1922 and 1923 this deposit was stripped by the American Minerals Company, but no material was shipped. The material reported to be diatomite is very white and light, but no detail is visible with the hand lens. Most of it is massive, but local beds a few inches thick, composed of half-inch layers, strike N. 20° E. and dip 15° NW. The deposit, which is overlain by soil containing abundant large volcanic boulders, grades downward into diatomite containing pebbles and fragments of lava, and then into sand cemented with tuffaceous material. A 15-foot tunnel was driven into the footwall and a bench perhaps 100 yards long and 15 yards wide cut along the footwall contact. No work has been done here recently.

Richter deposit is in sec. 20, T. 6 N., R. 6 W., M.D., 1½ miles west of Glen Ellen and south of Sonoma Mountain road. Owner is Herbert Richter, Sacramento, California.

This deposit consists of a porous white material with poorly defined bedding planes which suggest that the attitude is nearly vertical. The deposit is nearly 100 feet wide. A short tunnel leads to a stope, now caved, about 100 feet in diameter and 15 feet deep. E. Small states [26] that the Basalt Rock Company of Napa mined diatomite here about 1943 to manufacture "diatex brick."

Graphite

No graphite has been mined in recent years in Sonoma County, as the low-grade deposits cannot compete with the high-grade imported graphite. Fifty years ago a small production of graphite from Sonoma County was used for the manufacture of paint.

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[24] Laizure, C. McK, Sonoma County: California Min. Bur. Rept. 22, p. 334, 1926.
[25] Laizure, C. McK, op. cit., p. 334.
[26] Small, E., Personal communication.

McPherson Ranch deposit is in secs. 13 and 14, T. 9 N., R. 10 W., M.D., about 3½ miles west of Healdsburg.

Skinner Ranch deposit is in sec. 14, T. 4 N., R. 7 W., M.D., 4 miles south of Petaluma.

Occurrences of graphite are found at Porter Creek, in T. 8 N., R. 10 W.; two miles west of Cazadero; and in the Pine Flat district.

Limestone

A small amount of lime has been produced in Sonoma County by burning limestone. From 1880 until 1907 there was intermittent production, and again in 1937. Since that time no activity has been reported. The report by Logan [27] includes analyses of limestone samples from the Black Ranch deposit and from the Purviance Ranch deposit. This report also contains details concerning the Healdsburg Marble Company deposit and the Kohlman Gulch deposit.

Black Ranch deposit is in sec. 30, T. 11 N., R. 7 W., M.D. projected, about 6 miles north of Geyserville. The owner is unknown.

This deposit is an outcrop of hard compact limestone that stands above the surrounding chert and serpentine. Limestone was last mined from this deposit for a short time in 1937.

Healdsburg Marble Company deposit is in secs. 1 and 2, T. 9 N., R. 12 W., M.D., about 8 miles southwest of Skaggs Springs. The owner is unknown.

There is evidence that this deposit contains a large tonnage, but inasmuch as it is practically inaccessible, it remains undeveloped. The outcrop can be traced for more than 1000 feet and appears to be faulted in several places. The limestone is hard and compact, the color is white to red in varying degrees. The limestone is thought to be rather impure in some places, although no analyses are available to determine this point.

Kohlman Gulch deposit [28] is in sec. 13, T. 8 N., R. 13 W., M.D. projected, about 1½ miles north of Fort Ross. Owner is unknown. This prospect is undeveloped.

Purviance Ranch property [29] is in sec. 23 or 24?, T. 9 N., R. 10 W., M.D., 3½ miles west of Healdsburg. Owner is unknown. This property, formerly known as Ward Ranch, is an undeveloped prospect. No work has been done since 1926.

Magnesite

Many deposits of magnesite occur in Sonoma County. Although some of these were mined before 1921, no activity has been reported since that date. The total production for the county is in excess of 26,000 tons.

Because only large, high-grade deposits of magnesite can compete successfully with sea water as a source of magnesia, the future outlook for the mining of magnesite in Sonoma County is not encouraging.

A detailed report on magnesite, written by Bradley, contains a description of the Sonoma County deposits.[30]

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[27] Logan, C. A., Limestone in California: California Jour. Mines and Geology, vol. 43, pp. 333-334, 1947.

[28] Logan, C. A., op. cit., p. 334.

[29] Logan, C. A., op. cit., p. 334.

[30] Bradley, W. W., Magnesite in California: California Min. Bur. Bull. 79, pp. 89-97, 1925.

Occurrences include the Albertz Ranch deposit in sec. 25, T. 11 N., R. 11 W., M. D., 2 miles southwest of Cloverdale; the Battenburg Refractory Magnesite mine in sec. 32, T. 12 N., R. 10 W., M.D., 3 miles northeast of Cloverdale; the Brush deposit in sec. 15, T. 11 N., R. 10 W., M.D., 3 miles east of Cloverdale; the Burgans Ranch deposit in sec. 32, T. 12 N., R. 10 W., M.D., $3\frac{1}{2}$ miles northeast of Cloverdale; the Cummings deposit in sec. 23, T. 11 N., R. 11 W., M.D., 2 miles southwest of Cloverdale; the Madeira deposit in SW$\frac{1}{4}$ sec. 31, T. 9 N., R. 10 W., M.D., about $5\frac{1}{2}$ miles north of Guerneville; the Meeker Ranch deposit in secs. 2 and 3, T. 8 N., R. 11 W., M.D., 5 miles north of Guerneville; the Norton Ranch, in T. 10 N., R. 10 W., M.D., said to be 10 miles northwest of Healdsburg and 4 miles from Geyserville; the Sonoma Magnesite Company, in secs. 6, 7, 8, 17, and 20, T. 9 N., R. 11 W., M.D., 6 miles north of Cazadero; the Western Carbonic Acid Gas Company, in sec. 6, T. 8 N., R 10 W., M.D., 5 miles north of Guerneville; and the Yordi Ranch, in sec. 20, T. 11 N., R. 10 W., M.D., 2 miles southeast of Cloverdale.

Manganese

The manganese mines of Sonoma County had a recorded production of more than 1500 tons of manganese ore to the end of 1947. Inasmuch as the mines do not have ore that is rich enough to compete with foreign mines during peace-time, production has been mainly during the last two wars. The Aho mine has produced most of the ore from this county.

The ore all comes from the Franciscan group associated with chert and greenstone. The primary minerals are rhodochrosite and hematite, but many of the mines have not penetrated the surface deposits of black manganese oxide. Geology of the deposits has been described in more detail in Division of Mines Bulletin 125.[31]

Aho (Drum) mine is in secs. 15 and 16, T. 8 N., R. 12 W., M.D., about 5 miles west of Cazadero. Owner is Hilma K. Aho, Fort Ross, California.

The ore occurs in chert as a vertical bed with northwesterly strike. The deposit consists of oxide ore at the surface, but manganese carbonate is present at depth. Two adits, each about 200 feet long, have been driven to explore the oxide cropping. The bed, which is about 8 feet wide, has been traced for 200 feet, but its extent in depth has not been determined.

Mr. Al Aho said that the ore shipped in 1942 and 1944 assayed 45 percent or more MnO_2; it was sold to the Metals Reserve Company.

Murphy Ranch deposit is in sec. 3, T. 4 N., R. 8 W., M.D., about 6 miles west of Petaluma. It is owned by Joseph Moreda, Chileno Valley Road, Petaluma.

M. Vonson of Petaluma did a small amount of development work here during World War I. A pit 30 feet long and 10 feet wide exposed manganese oxide associated with a chert lens in Franciscan sandstone. The small tonnage of manganese ore found was too siliceous to be of commercial interest, and there has been no recent activity. The pit is filled with rubbish.

Occurrences of manganese in the county include the Baker Ranch deposit, in sec. 31, T. 11 N., R. 8 W., M.D., about $2\frac{1}{2}$ miles south of The Geysers; the Dillon and Seefeldt, in T. 9 N., R. 14 W., M.D., near

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[31] Trask, P. D., Wilson, I. F., and Simons, F. S., Manganese deposits of California. A summary report: California Div. Mines Bull. 125, pp. 89, 186-188, 1943.

Stewarts Point; the Dreamland, in sec. 6, T. 8 N., R. 8 W., M.D., 4 miles southeast of Healdsburg; the Foerchler, in sec. 34, T. 8 N., R. 7 W., M.D., 6 miles northeast of Santa Rosa; the Foss Ranch, in sec. 19, T. 11 N., R. 8 W., M.D., to the southeast of The Geysers; the Hayden, in sec. 7, T. 8 N., R. 12 W., M.D., about 5 miles west of Cazadero; the Holst-Weeks, in sec. 1, T. 7 N., R. 7 W., M.D., about 7 miles northeast of Santa Rosa; the Lucky Strike, in sec. 24, T. 11 N., R. 9 W., M.D., 1 mile southwest of The Geysers; the McDonald, in sec. 9, T. 10 N., R. 8 W., M.D., about 3 miles west of Pine Mountain; the Pine Flat, in secs. 9 and 10, T. 10 N., R. 8 W., M.D., about 2½ miles west of Pine Mountain; the Shanks and Copps Lease, in sec. 31, T. 10 N., R. 10 W., M.D., about 2 miles southeast of Skaggs Springs; the Sharp, in sec. 7, T. 8 N., R. 7 W., M.D., about 2½ miles east of Mark West Springs; the Skaggs Springs, in SE¼ sec. 13, T. 10 N., R. 11 W., M.D., 1 mile north of Skaggs Springs; the Warner, in SE¼ sec. 10, T. 10 N., R. 8 W., M.D., 2 miles west of Pine Mountain; the Wheeler prospect, in sec. 20, T. 10 N., R. 8 W., about 8 miles east of Geyserville; the White-O-Ranch, in sec. 8, T. 8 N., R. 9 W., M.D., about 3 miles west of Windsor; and the Wright, in sec. 7, T. 11 N., R. 10 W., M.D., about 2 miles north of Cloverdale.

Petroleum

Oil and gas have been encountered in the Petaluma area 5 miles east of Petaluma, but only two wells have been producers. Morse and Bailey have described this district,[32] and the geology of the area adjoining on the west has been covered by Johnson.[33]

The first shallow wells, one of which produced a little gas from a depth of 800 feet, were drilled about 1910. Deeper wells were drilled by the Shell Oil Company and others from 1927-35. The Shell Oil Company's Murphy 1 was 6385 feet deep.

The oldest rocks encountered are the Tolay volcanics, probably of early Pliocene age. This formation is more than 4000 feet thick; the base is not exposed, nor was it penetrated by the deepest test well. The portion penetrated, was from top to bottom, pyroclastic, andesitic, and basaltic. The Petaluma beds, which are 4000 feet thick, have been divided into a lower 500 to 600 feet of dark clay shales, and an upper section of clays, sands, and gravels. The basal beds are interbedded with the upper members of the Tolay volcanics. The Sonoma volcanics overlie the upper Petaluma beds with pronounced angular unconformity along the south edge of Sonoma Mountain north of the wells.

This gas- and oil-producing area lies immediately north of a wedge of the Franciscan group which has been elevated between two steeply dipping thrust faults, the Tolay fault and the Lakeville fault. The axes of the folds in the Petaluma beds are faulted, disconnected, and difficult to trace, but it is clear that northeast of the Franciscan wedge an open syncline is followed by an anticline the axis of which is offset by several faults. A small domed area, now complexly faulted, evidently was formed in the vicinity of the producing wells.

Only one well was producing in 1948. This well is a small producer and is owned by Trico Oil and Gas Company of San Francisco.

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[32] Morse, R. R., and Bailey, T. L., Geological observations in the Petaluma district, California: Geol. Soc. America Bull., vol. 46, pp. 1437-1456, 1935.

[33] Johnson, F. A., Petaluma region: California Div. Mines Bull. 118, pp. 622-627, 1943.

Wells have been drilled in two other localities—near Skaggs Springs, and 5 miles to the northeast of Healdsburg.

Tabulated data on wells drilled in Sonoma County between 1904 and 1940 are given in Division of Mines Bulletin 118.[34]

Quicksilver

In Sonoma County are quicksilver deposits which were among the first discovered in California. The initial recorded production in the county was made in January 1874 from the Sonoma mine, but the Pioneer mine may have been in production as early as 1861.[35] Between 1873 and the end of 1945 the total county production was 97,116 flasks. Of this, 38,649 flasks came from the Western Mayacmas district and one isolated mine at Skaggs Springs, and 58,467 flasks came from the Guerneville district.

The Guerneville and Western Mayacmas districts are underlain by rocks of the Upper Jurassic (?) Franciscan group; these rocks are mainly sandstone with some interbedded shale and chert. Dike-like bodies of serpentine, which are somewhat younger than the Franciscan rock, occur in wide fault zones that strike in a northwesterly direction. The ore shoots are contained in the parts of the serpentine bodies that have altered to silica-carbonate rock. In the Western Mayacmas district the highest parts of the main range are covered by tilted andesitic flows and tuffs known as the Sonoma volcanics, probably of Pliocene age.

A very complete geological report on the Guerneville district has been written by Myers and Everhart.[36] The same type of report on the Western Mayacmas district has been written by Bailey.[37] A map prepared by Jenkins [38] shows the location of quicksilver deposits in California and gives production data. Other publications concerning the quicksilver resources of California have been written by Bradley,[39] Ransome and Kellogg,[40] and Forstner.[41]

Anne Belcher mine [42] is in sec. 4, T. 10 N., R. 8 W., M.D., about 1½ miles north of Pine Flat. The owner is John D. Grant, of Healdsburg, California.

This mine was formerly a part of the Lucky Stone group, located in 1870. The workings consist of an adit about 400 feet long which was driven for the purpose of exploring a narrow serpentine mass that is locally silicified. The adit is now caved. There has been no activity in recent years.

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[34] Geologic formations and economic development of the oil and gas fields of California: California Div. Mines Bull. 118, p. 661, 1943.

[35] Yale, C. G., Mines and mining in the states and territories west of the Rocky Mountains, U. S. Treasury Dept. 6th Annual Rept., p. 30, Washington, D. C., 1874.

[36] Myers, W. Bradley, and Everhart, Donald L., Quicksilver deposits of the Guerneville district, Sonoma County, California: California Jour. Mines and Geology, vol. 44, pp. 253-277, 1948.

[37] Bailey, E. H., Quicksilver deposits of the Western Mayacmas district, Sonoma County, California: California Div. Mines Rept. 42, pp. 199-230, 1946.

[38] Jenkins, O. P., Outline geologic map of California showing locations of quicksilver properties (Economic mineral map of California no. 1—Quicksilver) scale 1:1,000,000, California Div. Mines, 1939.

[39] Bradley, W. W., Quicksilver resources of California: California Min. Bur. Bull. 78, pp. 181-196, 1918.

[40] Ransome, A. L., and Kellogg, J. L., Quicksilver resources of California: California Div. Mines Rept. 35, pp. 368-369, 461-471, 1939.

[41] Forstner, William, The quicksilver resources of California: California Min. Bur. Bull. 27, pp. 35-39, 97-117, 1903.

[42] Bailey, E. H., op. cit., p. 228.

Bacon Consolidated group [43] is in secs. 11 and 12, T. 10 N., R. 8 W., M.D., half a mile south of Pine Mountain, partly in Lake County. The owner is unknown.

The group includes the Edith, Maud, St. George, Golden Gate, and Eagle mines. The property is abandoned. There is no record of work since 1903, and no record of production since 1877. Total recorded production is 300 flasks.

Black Bear mine [44] is in sec. 22, T. 11 N., R. 9 W., M.D., about 3 miles west of The Geysers. It is owned by Black Bear Mining Corp.; president, Charles Humbert, of Cloverdale, California, and is leased to Raymond Guyer of Mill Valley, California.

This mine, formerly known as the Kentuck or Kentucky, is said to have been opened in the 1870's. The only statement on record concerning its early output was made in 1888 by Becker [45] who credited it with a production of 54 flasks. The records also show that in 1900 some of the ore from the Black Bear mine was treated in the furnace of the Culver-Baer mine.

In 1943 about 700 feet of workings were accessible; according to the record, there are also caved workings which total about 500 feet. The cinnabar was found near the sandstone hanging wall of a single small stope and a short inclined shaft. During the period 1941-43, a few flasks of quicksilver were produced at the mine. It is idle at present.

Buckeye mine [46] is in secs. 3 and 4, T. 11 N., R. 9 W., M.D., about 4 miles northwest of The Geysers. It is owned by Carl A. Baumeister, Healdsburg, California.

The mine, located in 1918, was formerly the Mt. Vernon claim of the Cloverdale group which it adjoins. Work at the property was intermittent from 1864 to 1944. The Buckeye was developed by an open cut and two adits. The total length of the underground workings is about 1050 feet.

The cinnabar occurs as a paint or finely crystalline encrustation in a lens of fractured chert that dips northwestward.

A geologic map of the property is contained in Bailey's report.

Cinnabar King group [47] is located in secs. 10 and 11, T. 10 N., R. 8 W., M.D., about 1 mile west of Pine Mountain. It is owned by H. B. Rosenberg, of Healdsburg, California.

The group includes the Cinnabar King, Champion, Paymaster, Goodenough, and Helen claims; and two millsites on the southwestern slope of Pine Mountain. Development of this property included a shaft 55 feet deep, about 800 feet of adits which are no longer accessible, and a few small open cuts. Exploration in the area has failed to reveal any minable ore bodies.

The cinnabar is sparsely disseminated in silica-carbonate rock containing pyrite and some hydrocarbons. The silica-carbonate lens strikes northwestward and dips to the southwest. The property is said to have produced a few flasks of quicksilver prior to 1890; it has been idle for many years.

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[43] Forstner, Wm., op. cit., p. 97.
Ransome, A. L., and Kellogg, J. L., op. cit., p. 385.

[44] Bailey, E. H., op. cit., pp. 222-223.

[45] Becker, G. F., Quicksilver deposits of the Pacific slope: U. S. Geol. Survey Mon. 13, p. 377, 1888.

[46] Bailey, E. H., op. cit., pp. 220-221.

[47] Forstner, Wm., op. cit., p. 98.

Cloverdale mine [48] is in the NE¼SW¼ sec. 4, T. 11 N., R. 9 W., M.D., 4 miles northwest of The Geysers. Owners are R. G. Flood, P. A. Flood, Enrico Pratti, Edward Pratti, Walter Sink, A. E. Skarboro.

The original group of claims comprised the Sunrise, Cloverdale, Mercury, Manzanita, Albian, Mattole, Mount Vernon, Philadelphia, and Waterloo, but it now includes only a few of these claims and a millsite. Ore was first discovered in 1863, and from 1872 to 1943 the mine was operated intermittently. Total production during that time was about 17,000 flasks. Development and mining were carried on in several glory holes and in many small stopes that were reached by about 10,000 feet of adits and drifts. In 1943 only one adit remained uncaved. A geologic map and a block diagram of the Cloverdale mine are included in the report by Bailey.[49]

The ore bodies are contained in two strata of chert in formations of the Franciscan group. In general the upper stratum of chert strikes northwestward and dips northeastward; the lower layer strikes eastward and is nearly vertical. Overlying the upper layer of chert are sandstone and shale. Both strata of chert are underlain by greenstone. The ore minerals are cinnabar and a small amount of native mercury.

Contact mine [50] is in the NW¼NE¼ sec. 5, T. 10 N., R. 8 W., M.D., about 4 miles southeast of The Geysers. The owner is Forrest Riley, P. O. Box 925, Corcoran, California.

The early records concerning this property are vague. At one time it was known as the Walker mine, and at another time as the Queen group of the Crown Point Mining Company. Prior to 1932, so far as is known, there was no production. Between 1932 and 1942, a total of 965 flasks of quicksilver were produced, but there is no record of production since that time.

The workings explore the contact of serpentine and sandstone along which bodies of silica-carbonate rock have formed. The general strike of the contact is eastward; the dip is to the north. The ore contains significant amounts of both cinnabar and native mercury in silica-carbonate rock, in the sandstone, and locally in the serpentine. In part of the mine a 1- to 4-inch vein of cinnabar lay along the contact. A geologic and underground map of this mine is in Bailey's report.[51]

Crystal mine [52] is in the NE¼NE¼ sec. 6, and NW¼NW¼ sec. 5, T. 10 N., R. 8 W., M.D., 4 miles southeast of The Geysers. The owner is H. A. Samson, of Healdsburg, California.

This mine, which was discovered some time before 1877, has been known as the Pacific, Red Cloud, and Abbey. Development work, carried on intermittently, resulted in about 2000 feet of workings which explored several silica-carbonate lenses, but no sizable ore bodies were encountered. In 1943 only 600 feet of the workings were accessible. No work has been done in recent years, and no production has been recorded.

Culver-Baer mine [53] is in secs. 23, 24, and 25, T. 11 N., R. 9 W., M.D., 1½ miles southwest of The Geysers. The property is owned by Culver-

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[48] Bailey, E. H., op. cit., pp. 219-221.
Bradley, W. W., op. cit., pp. 183-185.
[49] Bailey, E. H., op. cit., pl. 30.
[50] Bailey, E. H., op. cit., pp. 226, 227.
[51] Bailey, E. H., op. cit., pl. 33.
[52] Bailey, E. H., op. cit., p. 228.
Forstner, Wm., op. cit., pp. 114, 115.
[53] Bailey, E. H., op. cit., pp. 223-224.
Bradley, W. W., op. cit., pp. 185-186.

Baer Mining Company, Cloverdale, California, and is leased to C. A. Baumeister, of Cloverdale, California.

Holdings include the former Lost Ledge or Oakland mine, and the Geyser, Missouri, and Clyde mines. Recent production came from the Geyser and Oakland mines. From 1872 to 1932 this property was worked intermittently; from 1932 to the end of 1947 it was worked almost continually. To the end of 1946 the total production exceeded 12,000 flasks.

The workings, in general, explore an elongated body of serpentine that has been locally converted to silica-carbonate rock. The serpentine is surrounded by sandstone and shale of the Franciscan group. A map showing the accessible workings, a geologic map, and a block diagram of the mine are included in the report by Bailey.[54]

In exploring this deposit, 8000 or more feet of workings were driven. The ore was mainly cinnabar, but native mercury and metacinnabar are reported to have been found. Pyrite, yellow solid hydrocarbons, and oily hydrocarbons also occur in small amounts with the ore.

Dewey's mine[55] is located in the NW¼SE¼ sec. 14, T. 11 N., R. 9 W., M.D., 1 mile west of The Geysers. The property is owned by The Geysers Development Company, and is under lease to Frank A. Dewey.

Dewey's mine includes the Wild Hog, Eagle Rock, Geyers, Big Red, and Cima workings. Work began in 1940, and since that time production has totaled more than 150 flasks. The workings consist of about 600 feet of adits and a few open cuts which explore a lens of serpentine that has been altered in places to silica-carbonate rock. The ore bodies are small but are rich and closely spaced. Cinnabar is the principal ore mined, but some native mercury has been found. Most of the ore is mined from an open cut.

Esperanza mine[56] is in the SE¼ sec. 10, T. 11 N., R. 9 W., M.D., 3 miles east of The Geysers. The owner is J. G. Cortelyou, 4168 Udal Street, San Diego 7, California.

Before 1918 this property was known as the Bright Hope mine. The earliest recorded production was made in 1917, since which time operations have been intermittent. Production totals about 2,000 flasks.

The workings consist of 10 adits of various lengths; two remain uncaved. These adits were driven through sandstone to explore a thin body of serpentine that has been locally altered to silica-carbonate rock. The ore is cinnabar filling fractures in sandstone and shale and also in disseminated grains. Some native mercury has recently been found.

The mine is active at the present time.

Eureka mine[57] is in sec. 32, T. 11 N., R. 8 W., M.D., 3 miles southeast of The Geysers. The owner is F. M. White, 3248 Encinal Avenue, Alameda, California.

The Eureka was located in 1860. For a time it was called the Flagstaff, but the original name was resumed before 1903. In 1870 during development work it is probable that a small amount of quicksilver was recovered. According to records, intermittent production since that time has totaled 18 flasks.

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[54] Bailey, E. H., op. cit., pl. 31.

[55] Bailey, E. H., op. cit., p. 222.

[56] Bailey, E. H., op. cit., p. 222.
Bradley, W. W., Sonoma County: California Min. Bur. Rept. 14, pt. 2, pp. 343-344, 1916.

[57] Bailey, E. H., op. cit., p. 225.
Forstner, Wm., op. cit., pp. 106-108.

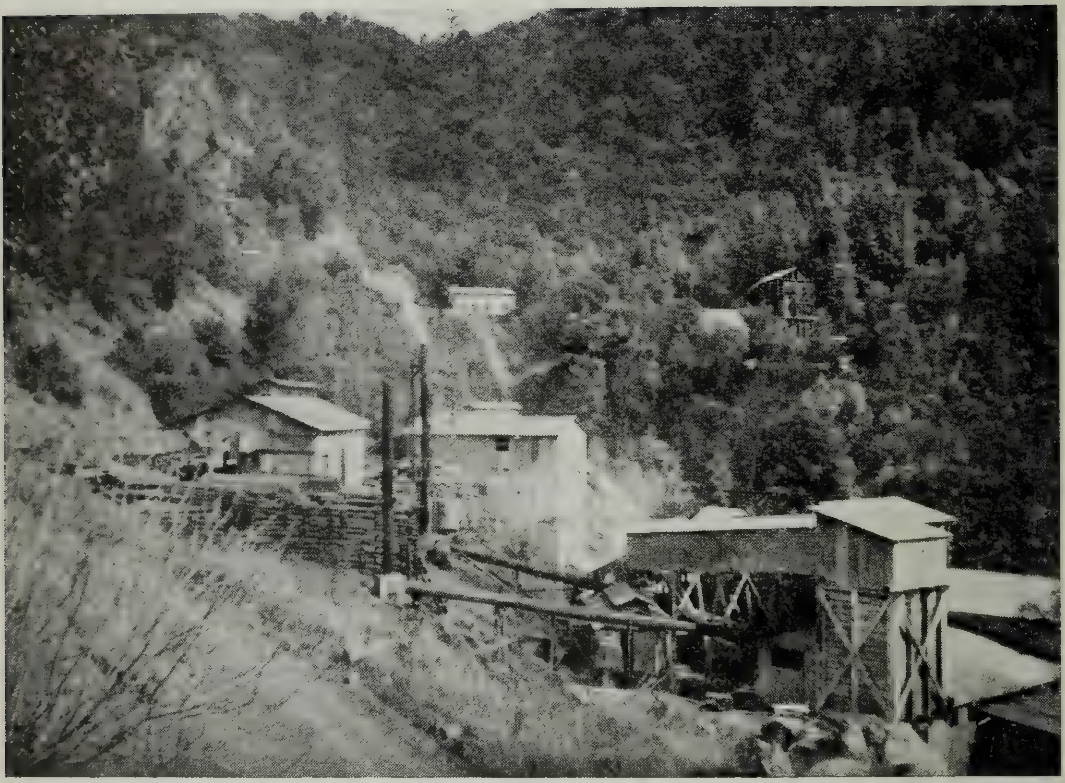

FIGURE 1. Mount Jackson mine.

The workings are reported to consist of 350 feet of drifts, a 300-foot adit, two shorter adits, a winze, and a shaft, all of which are now caved. They explored a thin silica-carbonate ledge at the contact of the sandstone and serpentine. The silica-carbonate rock contains cinnabar, native mercury, some metacinnabar, and both oily and black hydrocarbons.

Great Eastern mine (including the Mount Jackson mine and Roaring Lion prospect)[58] is in the NW¼NW¼ sec. 16, T. 8 N., R. 10 W., M.D., 4 miles by road to the north-northeast of Guerneville. Owner of the property is Sonoma Quicksilver Mines, Inc., 58 Sutter Street, San Francisco (president, H. D. Tudor; vice-president, E. F. Halloan; secretary-treasurer, E. R. Menary; superintendent, A. G. Mowry; mill superintendent, H. Larson.)

The Sonoma Quicksilver Mines, Inc., are the present operators of the Great Eastern mine, the Mount Jackson mine, and the Roaring Lion prospect.

The Mount Jackson and Great Eastern mines have been worked during three periods—1875-1906, 1915-19, and 1934 to date. At the end of 1945 production totaled 58,467 flasks.

The mines include 15,000 feet of horizontal workings on many levels, the deepest of which in 1948 was 775 feet. The ore is hand-trammed 350 feet to the ore bin next to the portal. It is then sledged to pass a 9-inch grizzly, crushed in a jaw crusher to a maximum size of 1½ inches, and fed into two rotary Gould furnaces.

The mine is now operated 6 days a week on two 8-hour shifts per day, and the mill, which treats about 125 tons a day, is operated on three 8-hour shifts per day. Exploratory work is done with diamond drills. A total of approximately 50 men are employed.

The geology of these deposits is fully covered in the report of Myers and Everhart.[59] Geologic maps and sections included in this report show the underground workings as of 1945.

The Mount Jackson and Great Eastern mines are in a region of serpentine and Franciscan sandstone. At the contact of these rocks is a ledge of highly opalized rock which strikes to the northwest and dips 50°-60° NE. The ore occurs in a soft decomposed material within the ledge, and cinnabar is generally found here in small seams with a quartz gangue.

Kissack prospect [60] is in the SE¼ sec. 4, T. 11 N., R. 9 W., M.D., about 4 miles northwest of The Geysers. The owner is L. D. Kissack of Cloverdale, California.

This property was formerly known by the following names: Amazon, Amazon Mail, Big Chief, Big Squaw, and Squaw. The first recorded production was in 1930. Since that time work has been intermittent, with production amounting to but a few flasks. The prospect is now inactive.

On one side of this property is the Cloverdale mine, and on the other side is the Buckeye mine. The geology of the Kissack is much the same as that of the adjoining areas.

Workings consist of several short adits and a few open cuts.

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[58] Myers, W. B., and Everhart, D. L., Quicksilver deposits of the Guerneville district, Sonoma County, California: California Jour. Mines and Geology, vol. 44, pp. 253-277, 1948.

[59] Myers and Everhart, op. cit., pp. 253-277, pls. 44-51.

[60] Bailey, E. H., op. cit., p. 221.

Last Chance mine [61] is in the NE¼ sec. 5, T. 10 N., R. 8 W., M.D., about 3 miles northwest of Pine Mountain. Owner is Banner Zeek, of Healdsburg, California.

This mine was located in 1860. A small production was recorded in 1902, but the property has been idle in recent years.

About 400 feet of workings on three levels explored the serpentine-sandstone contact. The serpentine is altered locally to silica-carbonate rock that contains a little cinnabar.

Rattlesnake mine [62] is in sec. 31, T. 11 N., R. 8 W., M.D., about 3 miles south of The Geysers. Owner is unknown.

The first production at this mine was in 1875. The last production was in 1920, since which time the property has been idle. The total output was 100 flasks.

Two adits and a winze were driven into a zone of sandstone and gangue containing native mercury. The workings are now caved.

Skaggs mine [63] is in secs. 23, 24, 25, and 26, T. 10 N., R. 11 W., and secs. 19 and 30, T. 10 N., R. 10 W., M.D., in the Skaggs Springs area. Owner was Leo Curtis, Skaggs Springs, California, in 1939.

The ore mineral is metacinnabar disseminated in a coarse greenish-gray sandstone. The ore was first found in 1925. The mine produced intermittently from 1931 to 1943 but has been idle since that time. The property was developed by an inclined shaft 100 feet deep from which drifts and crosscuts were driven at several levels.

Socrates mine [64] is in secs. 32 and 33, T. 11 N., R. 8 W., M.D., about 4 miles southeast of The Geysers. The owners are Helen Dillingham and Frances Vought.

This property, known before 1900 as the Pioneer mine, is said to have produced as early as 1861. The total production, although intermittent, probably exceeded 5,500 flasks at the end of World War II. The mine was developed from three adits. The total length of the underground workings is about 6,000 feet, most of which are now caved. A geologic map and sections are included with the report on this mine by Bailey.[65] The workings explore the contact of serpentine and sandstone. The contact strikes northwestward and dips to the southwest at the surface, but is almost vertical 400 feet below the surface. The serpentine at the contact is fractured and altered to silica-carbonate rock; the fractures contain cinnabar and native mercury.

Sonoma group [66] is in sec. 5, T. 10 N., R. 8 W., M.D., about 4½ miles southeast of The Geysers. Owner is unknown.

The group was formerly known as the Crown Point, Sonoma Consolidated, Old Sonoma, and New Sonoma.

The property has been idle for several years. During the time of operation, which began in 1873, a total of more than 100 flasks was produced, and it is possible that a considerable amount was produced that was not recorded.

At the present time, except for two adits, the underground workings are caved. Underground workings are said to total about 1,000 feet in length, and there are in addition several small open cuts on the property. The ore is said to be cinnabar and native mercury in silica-carbonate rock and in sandstone.

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[61] Bailey, E. H., op. cit., pp. 228-229.
[62] Bailey, E. H., op. cit., pp. 224-225.
[63] Ransome, A. L., and Kellogg, J. L., op. cit., pp. 469-470.
[64] Bailey, E. H., op. cit., pp. 225, 226.
[65] Bailey, E. H., op. cit., pl. 32.
[66] Bailey, E. H., op. cit., p. 228.
Bradley, W. W., op. cit., pp. 191, 192.

Yellowjacket mine [67] is in sec. 9, T. 9 N., R. 7 W., M.D., about 2 miles south of Mount St. Helena. Owner is G. P. Dyer (?).

The Yellowjacket was worked between 1871 and 1875. There is no official record of production, but Bailey estimates several dozen flasks probably were produced. The workings consisted of two shafts and five adits which explored several lenses of silica-carbonate rock. The workings are all caved.

Young Denver mine [68] is in the NE¼ sec. 5, T. 10 N., R. 8 W., M.D., about 3 miles northwest of Pine Mountain. Owner is Banner Zeek, of Healdsburg, California.

The workings, which consist of small open cuts and about 100 feet of drifts on several levels, expose some cinnabar in sheared serpentine. The mine has been idle in recent years.

Other properties. The following is a list of quicksilver deposits from which there is no record of production at any time. All of them have been abandoned for more than 40 years. References may be found in the tabulated list of mines and prospects.

Name	*Section*	*T.**	*R.**
Almaden, Incandescent and Tunnel site group	31, 32	11	8
Altamont Copper group	17	7	10
Boston group	3, 9, 10	10	8
Denver and Hope mines	4	10	8
Great Northern	4	10	8
Hurley prospect	4, 5	10	8
Jumbo mine	3, 10	10	8
Lookout group	32	11	8
Maricoma mine	36	10	8
Napa mine	11	10	8
Occidental and Healdsburg group	11	10	8
Old Chapman mine	25	10	9
	30	10	8
Walker prospect	8	8	10
Wall Springs	30	8	9

* All townships are north and all ranges are west of Mount Diablo base and meridian.

Sand and Gravel

Sand and gravel is produced or has recently been produced by 12 operators in Sonoma County that range from large organized companies to small producers. Five are on Russian River, three on Sonoma Creek, two on Dry Creek, and two on Santa Rosa Creek. For many years sand and gravel has been recovered from the creeks and rivers of Sonoma County for use in road surfacing and aggregates. In recent years the practice of washing and classifying these gravels has been adopted to produce a high quality aggregate. The larger sizes of gravel are commonly crushed.

Sand and gravel production accounts for a large part of the value of Sonoma County's mineral output.

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[67] Bailey, E. H., op. cit., p. 230.
[68] Bailey, E. H., op. cit., pp. 228-229.

Russian River

The best grade of gravel is found in the Russian River. It consists principally of quartz, chert, and sandstone derived from the large outcrop of the Franciscan group in the northern part of the county. The gravel north of Cloverdale has a deficiency of small-sized particles and is rather soft, for it has been water-worn to a comparatively limited degree. South of Healdsburg it contains a higher proportion of small-sized tough particles. In general a cubic yard of washed sand or gravel weighs about 1½ tons. River-run material from Dry Creek and Russian River is relatively free from organic substances.

In the process of mining sand and gravel the streams become roiled so that during the summer months resort owners on Russian River complain of muddy water. The result is that stone producers have to work behind dams. During periods in the winter months the hazard of high waters and caving banks prevents the use of digging equipment, and in order to keep the plants in operation, stock piles of river material are maintained.

Basalt Rock Company is located in the NE¼ sec. 28, T. 9 N., R. 9 W., M.D., in the southeast part of Healdsburg. Owner of the plant is the Basalt Rock Company, 8th Street, Napa, California (A. G. Streblow, president; Ed Provelli, vice-president; Jim Kennedy, superintendent, Healdsburg plant).

The Basalt Rock Company now has, in Healdsburg, a ready-mixed concrete plant, an asphalt plant, and a washing, sizing, and crushing plant.

The company takes from the Russian River at Healdsburg, material averaging 55 percent minus one-fourth of an inch. The specific gravity of the washed rock is as follows:

Size	*Specific gravity*
Minus ¼ inch	2.69
¼-¾ inch	2.68
¾-1½ inches	2.66
1½-2½ inches	2.63

At the plant 35 different sizes of aggregate can be produced, and the aggregate can be blended for use in specification-mixed concrete. The concrete made from this product has a 28-day strength ranging from 2000 psi. to 4000 psi. (psi. = pounds per square inch). The material is taken from the river banks by a 4-cubic-yard dragline and hauled to the washing and sizing plant in 14-cubic-yard trucks. The company has equipment for handling 400 tons per hour of river material. Plant storage has been provided for five sizes of sand (minus ¼ inch), eight sizes of gravel (¼ inch to 3 inches), and five sizes of crushed gravel (⅛ inch to 2½ inches).

To assure year-round operation of the plant, the company has provided for raw storage in the amount of 1½ million tons. During the months favorable to dredging, dragline operation is kept up to capacity and the material is divided between the plant and raw storage. In winter and during the time when there is a possibility that high stream waters will prevent dredging, the plant is kept supplied from raw storage. About 85 percent of the aggregate produced is shipped by rail. The plant is connected to the Northwestern Pacific Railroad by a spur.

Dry Creek Gravel Company is in the NW¼ sec. 29, T. 9 N., R. 9 W., M.D., about half a mile west of Healdsburg. Operator is James Cuneo, Healdsburg, California.

This company produces from the gravels of Dry Creek. The capacity of the washing plant is 200 to 250 cubic yards per shift. About 400 cubic yards of river-run material can be loaded per shift. The products stocked are sand, pea gravel, ¾-inch gravel, 1½-inch gravel, and oversize. Three men are employed.

Harvey Taylor Gravel Company is in the SE¼ sec. 20, T. 9 N., R. 9 W., M.D., about half a mile west of Healdsburg. Operator is Harvey Taylor, 103-1st Street, Healdsburg, California.

This company produces from the gravels of Dry Creek. A washing plant is now being constructed. With the equipment on the property, about 400 cubic yards of river-run gravel per shift can be loaded. Two men are employed.

Hein Bros. Basalt Rock Company is in the NE¼ sec. 16, T. 8 N., R. 9 W., M.D., about 2 miles west of Windsor. Operator is Hein Bros. Basalt Rock Company, Box 162, Petaluma, California.

This company started producing sand and gravel from the Russian River in March 1949. The capacity of the washing plant is 400 cubic yards per shift. Products stocked are concrete sand, pea gravel, ¾-inch gravel, 1½-inch gravel, and oversize. The sand and gravel are blended for specification-mixed concrete.

Maxwell Bros. plant is in sec. 29, T. 8 N., R. 9 W., M.D., about 1 mile northeast of Mirabel Park. Operator is W. Carter Maxwell, 928 Sonoma Avenue, Santa Rosa, California.

This company started producing sand and gravel from the Russian River in 1936. The capacity of the washing plant is 250 cubic yards per shift. The products stocked are plaster sand, concrete sand, pea gravel, ¾-inch gravel, 1¼-inch gravel, 1½-inch gravel, and oversize. Fill rock and road metal are also produced. Seven men are employed. The land is leased from the Wohler Ranch.

Mirabel Sand & Gravel Company is located in the NW¼ sec. 31, T. 8 N., R. 9 W., M.D., half a mile northwest of Mirabel Park. Operator is Simon Camgros, San Rafael, California.

Sand and gravel has been taken from this area since 1927 by Simon Camgros, who is the present owner and operator of the plant. Most of the product of the washing plant is used as concrete aggregate by a ready-mix concrete plant in San Rafael which is also owned by Mr. Camgros.

Sand and gravel is taken from the river and beach of the Russian River by two slackline cable excavators and one Northwest dragline. One scraper delivers directly to the washing plant, and the other scraper and the dragline load into trucks which dump into an elevator at the base of the washing plant. The river-run material is washed and sized, then stored in concrete bunkers from which it is loaded by gravity into trucks for delivery. The washing plant has a capacity of about 400 cubic yards per shift, and the products are as follows:

Size	*Cubic yards*
Sand	250
4/16-inch pea gravel	25
½-inch pea gravel	15
¾-inch gravel	75
1½-inch rock	30

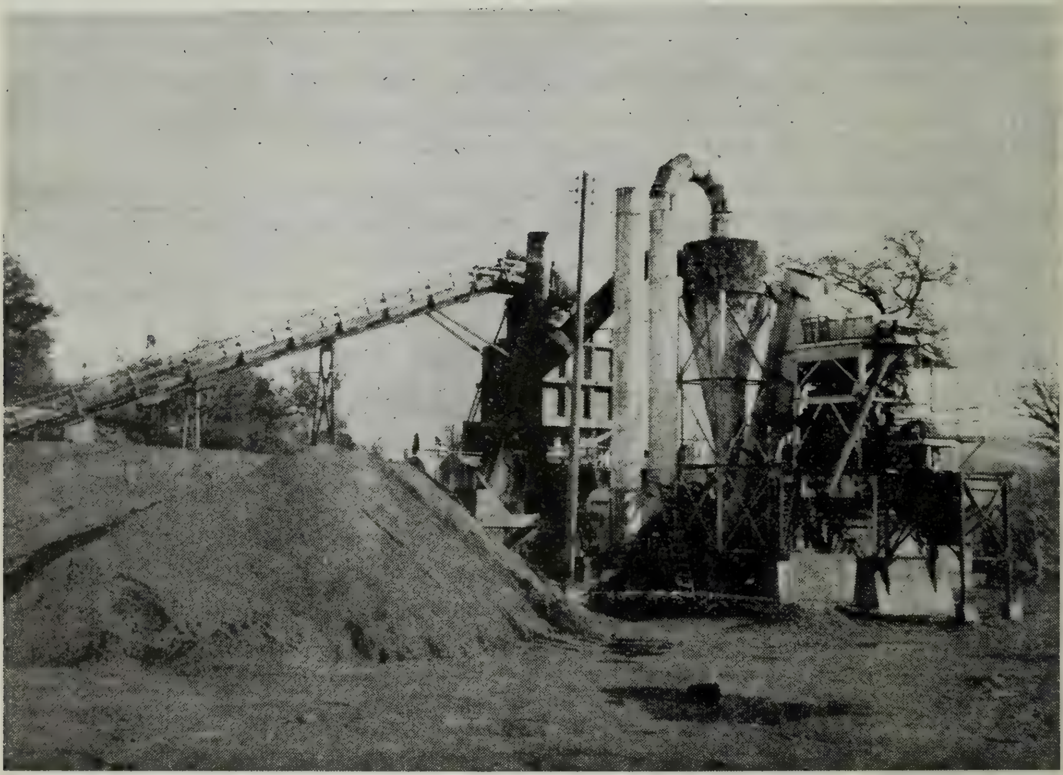

FIGURE 2. Spaletta asphalt mixing plant near Santa Rosa.

Each year the sand and gravel previously removed is replaced during the period of high water. The material consists of sandstone, chert, quartzite, and serpentine. The particles are well rounded and have a high strength.

When working behind the dams the slackline cable excavators have a limited use and most of the loading into trucks is done by the dragline. When the dragline is inoperative the washing plant is supplied with river-run gravel by a bulldozer which feeds from a stock pile into the elevator boot. The capacity of the present equipment of this company is about 1000 cubic yards of river-run gravel per shift. Eight men are employed in this area by the Mirabel Company.

Siri & King Gravel Plant is in the NW¼SW¼ sec. 7, T. 7 N., R. 10 W., M.D., on the northern edge of Monte Rio. Operator is Siri & King, Box 361, Guerneville, California.

This company leases 900 feet of the beach at Monte Rio, Clar's quarry, and owns the Siri & King quarry. The beach has been worked for gravel since about 1900; the present operator started work there in 1942. Equipment consists of seven trucks, four Caterpillar tractors, a motor patrol, and a three-fourths yard Quickway shovel. The equipment has a capacity of about 500 yards per shift. The material is sold for general construction without being washed and sized; it is clean enough to be used as concrete aggregate. The gravel is pushed by a bulldozer onto a truckloading ramp.

The gravel supply of the beach area is replenished each year by the high waters of the Russian River. This gravel is supplied to users within an 8-mile radius of Monte Rio.

Ten men are employed.

Santa Rosa Creek

Gravel of commercial grade is obtained from Santa Rosa Creek in the Rincon district between 2 and 3 miles east of Santa Rosa. The gravel varies in size from fine sand to cobbles which sometimes are a foot or more in diameter. The gravel is composed predominantly of diabase porphyry and highly vesicular basalt, but Franciscan sandstone is present also.

Onsrud gravel pit is in sec. 18, T. 7 N., R. 7 W., M.D. (projected), on the north side of Santa Rosa Creek. Operator is Onsrud Construction Company.

The Onsrud Construction Company formerly operated a washing plant on Santa Rosa Creek about a quarter of a mile northeast of the Spaletta pit. The plant was dismantled during the summer of 1948.

Spaletta gravel pit is in sec. 18, T. 7 N., R. 7 W., M.D. (projected), on the south side of Santa Rosa Creek 2½ miles northeast of the court house at Santa Rosa. Operator is Joseph & DePaul, Box 369, Santa Rosa, California.

The pit is approximately 1000 feet in diameter and averages 10 feet in depth. The gravel is loosened with rooters where necessary and taken with carry-all scrapers to the screening plant at the edge of the pit. Here it is passed over a grizzly where boulders greater than about 8 inches in diameter are rejected. Gravel which passes through the grizzly is reduced to minus one inch with a jaw crusher and crushing rolls in closed circuit with a shaking screen that produces three sizes. The plus 2-inch material is reduced in the jaw crusher; the minus 2-inch, plus 1-inch product passes through the rolls. The minus 1-inch product is taken by a belt conveyor to the top of wooden bins where a double-decked shaking screen produces several sizes.

The capacity of the plant is 500 cubic yards per shift. An asphalt mixing plant close to the pit absorbs a large part of the output.

Sonoma Creek

Sonoma Creek from tidewater to about a mile northwest of Agua Caliente has supplied sand and gravel. The gravel is unsorted, ranging in size from sand to cobbles 6 inches or more in diameter. It is predominantly andesite and basalt, but cobbles of olivine basalt, vesicular lava, and porphyry containing feldspar phenocrysts are not rare. Pieces of chert are occasionally encountered. White banded rhyolite pebbles are found in the creek above Agua Caliente but become progressively less common downstream.

The operations on Sonoma Creek are not large, but near Sonoma from 45 to 50 feet of gravel lying on clay has been found. The clay has not been penetrated.

Palmer pit is in sec. 30, T. 5 N., R. 5 W., M.D. (projected), on Sonoma Creek 2½ miles south of Sonoma. Operator is C. E. Palmer.

Gravel from the creek bed is loaded into trucks with a drag line scraper. There is no screening or washing equipment. The material is used for fill.

Serres pit is in sec. 35, T. 6 N., R. 6 W., M.D. (projected), on Sonoma Creek about 1 mile northwest of Agua Caliente. Operator is J. P. Serres, who has a screening plant on the east side of the creek which has not been used for 2 or 3 years.

Wrobel pit is in sec. 13, T. 5 N., R. 6 W., M.D. (projected), on the east side of Sonoma Creek about 1 mile southwest of the center of Sonoma. Operator is L. J. Wrobel.

The washing and screening plant was rebuilt during the summer of 1948. Gravel is taken from the river bottom with an electrically operated scraper and passed over a grizzly which rejects cobbles greater than 6 inches in diameter. The minus 6-inch material is screened with a trommel. A gravel pump capable of handling rocks 6 inches in size is also available to supply gravel to the trommel. It is mounted in a 36-foot landing craft and is driven by a 240 horsepower engine.

The trommel separates five sizes. Sand is cleaned in a rake classifier and will be further sized when additional equipment is obtained. Pea gravel, ¾-inch rock, and drain rock (¾-inch to 2½-inch) are stored in bins. Oversize (plus 2½ inch) is crushed and passed through the trommel again.

Crushed and Broken Stone

Crushed and broken stone may be divided into two general classifications. The first is carefully sized stone of more or less exact specifications used for concrete aggregate and road metal. Specifications cover the strength and toughness of the rock in addition to the sizes of the finished product. The basalts and andesites of the Sonoma volcanics are a convenient and favorite source. Equally good crushed rock is prepared from cobbles rejected in treating creek gravels. Gravel washing plants in Sonoma County usually produce crushed rock as an integrated part of the washing process.

The second type of product is unsized pit-run material used for subgrades and fills. Good compaction is the physical property desired, but availability is the primary consideration. The tuff and breccia members of the Sonoma volcanics are widely used.

The production of crushed stone requires an elaborate plant consisting of large crushers and screens, storage facilities, and loading equipment. Such operations ordinarily are permanent. An operation producing fill material, however, is likely to be temporary or intermittent. Many are operated on a royalty basis by the county highway department, some by contractors; and there are a few which sell material to private customers. They may be large or small, opened for one job and abandoned, or operated intermittently over a period of many years whenever roads are repaired in the vicinity.

It has not been possible to visit all the plants in Sonoma County which produce crushed and broken stone, nor are those which are described in the following pages necessarily of major importance. It is hoped, however, that the tabulated list of mines and mineral deposits includes all the active or recently active pits and quarries.

Fairville quarry is in sec. 17, T. 4 N., R. 5 W., M.D. (projected), at the location designated, ''Quarries'' north of Seares Point on the Mare Island quadrangle. Product was crushed stone.

The Sonoma volcanics dip here about 30° SE. A gray porphyry with clouds of phenocrysts is cut by joints so closely spaced that pieces greater than 2 feet in diameter are rare. The porphyry is underlain by a porous rock which is essentially an open network of feldspar crystals.

This quarry has not been operated since 1910.

Hein Bros. Basalt Rock Company is in sec. 3, T. 4 N., R. 7 W., M.D., at Haystack Landing on U. S. Highway 101 east of Petaluma. Operator is Hein Bros. Basalt Rock Company (Mark Hein, president, Box 162, Petaluma, California). The product is crushed stone.

The Hein Brothers quarry was opened in August 1925 in a basalt flow 100 feet thick which caps a small hill. The flow, which is scoriaceous near the top and bottom, grades inward to a vesicular black porphyry. The central part is a fine-grained tough basalt.

The quarry has a face about 50 feet high. Thirty-foot holes are drilled into the toe of the face, and when these are blasted the upper part of the face caves. Two trucks which are loaded by a steam shovel carry the broken rock to the primary crusher which is just below the level of the quarry floor.

The crushing and screening plant, which is flexible enough to meet the specifications of any order, is located on the hillside between the quarry and the highway. Equipment includes two trommels to remove fines from the primary crusher product, secondary cone crushers, crushing rolls, and double-decked vibrating screens. Belt conveyers and a bucket elevator are used.

The company also has at Haystack Landing a ready-mixed concrete plant and an asphalt mixing plant.

Joulie quarry is in sec. 10, T. 6 N., R. 6 W., M.D., on Trinity Road 0.8 mile east of State Highway 12. Owner is F. B. Joulie. The product is fill material.

Altered volcanics consisting of a reddish porphyry with altered feldspar phenocrysts and a loosely cemented breccia occurs just off Trinity Road. An area about 1000 feet in diameter has been stripped. Scrapers are used to bring the material down to the level of the road. The county uses it for road work.

Malnati quarry is in sec. 17, T. 4 N., R. 7 W., M.D., about 3 miles south of Petaluma. Owner is Charles Malnati. The product is fill material.

A quarry face 75 feet long and 20 feet high has been opened in diabase. No equipment is on the property. The product is occasionally used for local road work.

Meachim Hill quarry is in sec. 12, T. 5 N., R. 8 W., M.D. (projected), on Meachim Hill, 2½ miles south of Cotati. Owners are E. H. and M. F. Maggard. The product is fill material.

This pit has been opened in a series of volcanics which caps Meachim Hill. A thin flow of olivine basalt lies beneath beds of tuff and scoria.

The pit is operated by the county and occasionally by others under lease. Little blasting is necessary, but a rooter is used to break up the rock for handling with a power shovel. Crushing, screening, and loading equipment is present but is no longer serviceable. Shovels load pit-run material directly into trucks. The pit is 500 to 1000 feet in diameter, and has a face 60 feet high.

O'Connor quarry is in sec. 11, T. 7 N., R. 8 W., M.D., about 2 miles north of Santa Rosa on U. S. Highway 101. Owner is Robert O'Connor. The product is fill material.

A face 150 feet long and 80 feet high has been made in a light-colored, porous tuff. The material was used in the construction of the Santa Rosa bypass.

Onsrud quarry is located in sec. 11, T. 7 N., R. 8 W., M.D., on U. S. Highway 101 about 1½ miles north of Santa Rosa. The owners are Peter Onsrud and Carl Sullivan. Product is fill material.

This pit is in porous light-gray tuff of the Sonoma volcanics. It contains a 30-foot bed of chocolate-brown shaly material.

Blasting is occasionally necessary. The material was used in the construction of the Santa Rosa bypass.

Petaluma Hill Road quarry is in sec. 36, T. 7 N., R. 8 W., M.D., on Petaluma Hill Road 3 miles from Santa Rosa. The owner is Lewis Zamoroni, 3015 Petaluma Hill Road, Santa Rosa, California. Product is fill material.

This quarry is a large pit in the Sonoma volcanics, here represented by light-gray, sandy tuff, with a minor amount of vesicular lava and fine-grained brick-red tuff.

Vertical holes are blasted from irregular benches.

The material was used in the construction of the Santa Rosa bypass.

Stony Point (Wilson) quarry is in sec. 34, T. 6 N., R. 8 W., M.D. (projected), north of Stony Point and about 8 miles south of Santa Rosa. Owners are the heirs of W. A. Wilson.

Two pits have been opened in the flows, tuff, and breccia of the Sonoma volcanics which are horizontal or dipping up to 30°.

Crushing, screening, and loading equipment has been installed at several times, but it is no longer serviceable.

The county and others operate the property intermittently on a royalty basis. The product is fill material.

Williams quarry is in sec. 3, T. 6 N., R. 7 W., M.D., in Bennett Valley, 6 miles southeast of Santa Rosa. Owner is F. B. Williams.

The volcanics here consist of a breccia of angular volcanic fragments in a crumbling mudlike matrix.

A small pit, which is partly flooded, has been excavated below ground level.

The county occasionally uses material from this pit for fill.

Zaney Gravels quarry is in sec. 7, T. 6 N., R. 7 W., M.D. (projected), east of the Petaluma Hill Road, 4½ miles southeast of Santa Rosa. Operator is A. B. Siri, Inc., 1537 Cleavland Avenue, Santa Rosa. The product is crushed stone for grading and paving.

Crushed stone is obtained from a lava flow 150 feet thick, on the southwest flank of Taylor Mountain. The flow lies between tuff beds. The underlying tuff is sandy and contains partly rounded cobbles up to 2 inches in diameter. The lava is a hard, bluish, aphanitic rock which is so cut by joints that sound pieces greater than a foot in diameter are uncommon. Alteration has occurred along the joints.

Blasting is seldom necessary. Formerly several benches were maintained with bulldozers. Present practice is to scrape the rock from above the face over the edge with one bulldozer and to use a second bulldozer to bring it to the feed bin. A portable plant has been installed, consisting of a belt feeder, grizzly, jaw crusher, and shaking screen. Oversize from the screen is passed through rolls and screened again.

"Flagstones" and Colored Building Stone

''Flagstones'' and colored building stone are produced from quarries in rhyolite flows on both sides of Sonoma Valley near Glen Ellen. Flagstones are procured from banded flows which split readily along well-defined and closely spaced parting planes. Multi-colored stone is obtained from deposits of altered rhyolite.

These quarries are all small, and supply a local market. The operator with one or two helpers breaks out stone from time to time as the demand arises. Light charges are used to blast down rock which is pried out onto the quarry floor and trimmed by hand.

Candy Rock quarry is in sec. 3, T. 6 N., R. 6 W., M.D. (projected), in Nuns Canyon 1½ miles from State Highway 12. The owner is V. O. Campbell.

Highly colored building blocks, gray, green, and pink, are produced very occasionally by the owner and a helper. The rock, which is an altered rhyolite, is banded but breaks into blocks along joints heavily stained with limonite. In general the blocks are pink at the center with a very irregular outer zone of gray or green, suggesting alteration by solutions which worked in from the joints. The blocks are cut by cracks up to ⅒ of an inch wide, in which tiny quartz crystals and cubes of pyrite partially altered to limonite have formed. In places the rock is spotted with blebs of opal, while in other sections there are small chalky looking amygdules partially filling rectangular voids. Here and there irregular calcite veinlets as much as ⅜ of an inch wide cut the rock.

Gerberding quarry is located in sec. 10, T. 6 N., R. 6 W., M.D. (projected). It is northwest of the Valley of the Moon quarry, north of Trinity Road about half a mile from State Highway 12. It is leased by Richard Pittock.

This quarry produced much stone, but little valuable material remains. A porous banded rhyolite occurs here, which is, however, less uniform than that at the neighboring Valley of the Moon quarry. Red bands or red films are common along the porous parting planes. The quarry now in use is a pit approximately 100 feet by 200 feet in plan and 20 feet deep, but there are in addition several abandoned openings as large as this.

Gordenker quarry is in sec. 26, T. 7 N., R. 7 W., M.D. (projected), about 1½ miles west of Lawndale on Bennett Mountain. The owner is J. J. Conney; Rodney Gordenker is lessee.

Rodney Gordenker leased this deposit of banded rhyolite early in 1948 and produces both blocks and flagstones. The rhyolite is harder than at the Valley of the Moon quarry, the largest and oldest of the Sonoma County producers, but it splits less readily. Layers which are 1/10- to ⅛-inch thick are alternately pink and green or white. Occasionally along some seams there is a connected opening an inch or two long. The beds are nearly horizontal and grade successively into scoria and perlite.

A bench 15 feet wide and 60 feet long has been made. The rock is split by hand and broken transversely with a hydraulic cutter.

Johnson quarry is in sec. 10, T. 6 N., R. 6 W., M.D., near Trinity Road about 1 mile from State Highway 12. Owner is William Youngman.

Flagstones are produced here from rhyolite which readily split into flat slabs an inch or more thick along planes which strike N. 55° W. and dip 60° SW. The rock is gray, fairly hard, and contains layers of tiny more or less connected voids. An occasional phenocryst of plagioclase is large enough to cut one or two of the layers. The quarry now has a face 20 feet high and approximately 100 feet long.

Rainbow quarry is in sec. 36, T. 6 N., R. 6 W., M.D., about half a mile east of the Agua Caliente post office. Operator is John Sitenga, contracting stone mason, of El Verano, California.

Both flagstones and building stone are produced from the Rainbow quarry, which consists of three openings, each about 15 yards in diameter at one level along the hillside and within 100 yards of each other. The rock in the southeast part of the deposit is a soft, blue-gray rhyolite which splits readily along layers of flattened vugs 1 to 3 inches apart. Along some of these parting planes there is a red stain of iron. To the southwest this rock abuts against perlite in a steeply dipping fault contact with strikes northwestward.

At the northwest end of the deposit perlite is not exposed. The rock quarried is porous, ashy looking, stained yellow and red with iron, and crumbles easily. Both varieties have a mica-like sparkle caused by very small quartz crystals.

It has been found that rock within 3 feet of the surface is weathered and must be discarded. Splitting is done with a blunt axe-like tool. Freshly quarried stone is damp and crumbles instead of splitting cleanly.

Valley of the Moon (Cabrol) quarry is in sec. 10, T. 6 N., R. 6 W., M.D., south of Trinity Road about half a mile from State Highway 12. Owner is S. Cabrol. The property is leased to R. J. Johns.

This is one of the largest producers of flagstones in the county and has operated more or less continuously since 1928. The rock is a blue-gray banded rhyolite which readily splits into layers 1 or 2 inches thick along parting planes formed by tiny elongated vesicles. The layers are nearly horizontal and almost parallel except near the edges of the deposit where they are somewhat distorted. This banded rhyolite occurs as irregular masses in the Sonoma volcanics. In quarrying, occasional blasting with light charges of slow dynamite is necessary. Blocks are pried out and hauled onto the quarry floor where they are split and trimmed by hand.

TABULATION OF MINES AND MINERAL DEPOSITS

Name of Deposit refers to the name of a claim, a group of claims, a mine, or a quarry. In cases where a deposit has been known by more than one name, reference is made to the last name by which it was known.

Name of Owner or Operator refers to the last-known owner or operator.

Location is the latest available. In some cases there are discrepancies in the records which make doubtful the precise location of certain deposits. *Sec.* denotes section, *T.* denotes township, *R.* denotes range, and *M.D.* denotes Mount Diablo base and meridian. All locations in Sonoma County are North township and West range, as measured on the Mount Diablo base and meridian. In areas that have not been surveyed into sections, locations have been approximated by projecting land lines.

Remarks and References. Full titles are given in the bibliography.

Inasmuch as the tabulating of all occurrences in the county is impracticable, this list is incomplete. It is hoped that anyone who finds omissions or other forms of error will call them to the attention of the State Division of Mines in San Francisco.

Clay

Number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B & M		
1	Beltane		2	6	6	MD	Clay	Dietrich, W. F. 28, pp. 227, 291.
2	Weise Clay Pit	Shirley E. Weise, Glen Ellen	3	6	6	MD (proj.)	Clay	Dietrich, W. F. 28, pp. 227-228, 262.

Chromite

Number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B & M		
3	Baldrini Prospect	E. L. Baldrini, Camp Meeker	27	7	10	MD		
4	Barnes Mines	Italian Swiss Colony, Asti	30, 31, 32	11	10			Dow, D. H. 46, p. 26.
	Burl: see Laton							
	Camp Meeker: see Sonoma Chrome, Inc.							
	Culver-Baer: see Red Hill							
	Eakles Bros.: see Rough Crossing							
	Ferrera (Ferrari): see Barnes							

5	Gaver Prospect	A. P. Gaver, Petaluma	27	7	10			Dow, D. H. 46, p. 26.
	Juniper Ridge: see Red Hill							
	Jadun: see Barnes							
	Key: see Red Hill							
6	Laton Mine	A. J. and C. R. Laton, Cazadero	NE¼, SE¼, 13	9	12			Dow, D. H. 46, p. 26.
	Lock: see Red Hill							
	Lock and Key: see Red Hill							
	Lone Bird: see Laton							
7	Madeira Claim	Henry Doelger, Healdsburg	31	9	10			Bradley, W. W. 18, p. 201. Dow, D. H. 46, p. 27.
	McMahon Ranch: see Barnes							
	Meeker: see Sonoma Chrome, Inc.							
	Parameter Ranch: see Laton							
	Patentes: see Barnes							
	Pine Flat: see Warner and Clark							
	Rattlesnake: see Laton							
8	Red Hill Claim	E. A. Truitt, Healdsburg	15, 22	11	9			Dow, D. H. 46, pp. 27-28.
	Red Slide: see Laton							
9	Rough Crossing Claim		21	9	11			Dow, D. H. 46, p. 28.
	St. Charles: see Welch							

Chromite—Continued

Number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B & M		
	Serpentine: see Laton							
10	Shanks and Copps Claim	E. D. Thompson	13	10	11			Bradley, W. W. 18, p. 203.
	Slats: see Laton							
11	Sonoma Chrome, Inc.	Florence M. Button	15, 16, 17	7	10			Dow, D. H. 46, p. 28.
	Wanderer: see Barnes							
12	Warner & Clark Claim	Anna Warner, Pine Flat	10	10	8			Dow, D. H. 46, p. 29.
13	Welch Prospect	T. G. Sinclair, Guerneville	22	9	11			Caldwell, F. B. 18, pages unnumbered.
	Yellow Streak: see Laton							

Coal

Number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B & M		
14	Pierson Mine	Wikiup Rancho, Santa Rosa	27	8	8	MD	Coal	Museum specimen 18428. Laizure, C. McK 26, p. 333.
15	Taylor Ranch	E. M. Weaver, Santa Rosa	NW¼, 31	7	7	MD	Coal	Museum speciment 11637. Laizure, C. McK 26, p. 333. Irelan, William, 88, p. 634.
16			33	6	6	MD (proj.)	Coal	Occurrence.*
17	Rule's Ranch		SE¼, 19	8	12	MD (proj.)	Coal	Occurrence.

* Not shown on map.

Copper

Number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B & M		
18	Altamont	F. M. Button, Camp Meeker	17	7	10	MD		Aubury, L. E., 08, p. 167.
19	Archer		30	8	9	MD		Aubury, L. E., 08, p. 166.
20	Baby Jack & Earl Clare		3, 4	9	10	MD		Aubury, L. E., 08, p. 167, 168.
21	Cornucopia		33, 34	12	9	MD		Bradley, W. W., 16, p. 320.
	Earl Clare: see Baby Jack							
22	Gray Prospect		26	9	12	MD		Bradley, W. W., 16, p. 320.
23	Grizzly		5	9	10	MD		Aubury, L. E., 08, p. 167.
	Healdsburg: see Cornucopia							
	Squaw Creek: see Cornucopia							
24	Wall Tract		30	8	9	MD		Aubury, L. E., 08, p. 166.
25	Ward Tract		22	9	10	MD		Aubury, L. E., 08, p. 167.

Diatomaceous Earth

Number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B & M		
	Collings Deposit: see Goodman Bros. Deposit							
26	Felder Deposit	Leo Felder, Box 248, Sonoma	9	5	6	MD (proj.)		
	Goldstein Ranch: see Mt. Pisgah Vineyard Deposit							
27	Goodman Bros. Deposit		10	8	8	MD		Laizure, C. McK, 26, p. 334.
28	Mt. Pisgah Vineyard Deposit	Louis Martini, St. Helena	30	6	5	MD		Laizure, C. McK, 26, p. 334.
29	Richter Deposit	Herbert Richter	20	6	6	MD (proj.)		

Graphite

Number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B & M		
30	McPherson Ranch Deposit		13, 14	9	10	MD		Laizure, C. McK, 26, p. 335.
31	Skinner Ranch Deposit		14	4	7	MD		Aubury, L. E., 06, p. 281.

Limestone

Number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B & M		
32	Black Ranch Deposit		30	11	9	MD (proj.)	Limestone	Last mined, 1937. Logan, C. A. 47, p. 333.
33	Healdsburg Marble Company		1, 2	9	12	MD	Limestone	Undeveloped. Logan, C. A. 47, p. 333.
34	Kohlman Gulch		13	8	13	MD (proj.)	Limestone	Undeveolped. Logan, C. A. 47, p. 334.
35	Purviance Ranch		23 or 24	9	10	MD	Limestone	Undeveloped. Logan, C. A. 47, p. 334.
	Ward Ranch: see Purviance Ranch							

Magnesite

Number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B & M		
36	Albertz Ranch Deposit		24	11	11	MD	Magnesite	Undeveloped. Bradley, W. W. 25, p. 89.
37	Battenburg Refractory Magnesite Mine		32	12	10	MD	Magnesite	Mined prior to 1921. Bradley, W. W. 25, pp. 89-91.
38	Brush Deposit		15	11	10	MD	Magnesite	Mined prior to 1909. Bradley, W. W. 16, p. 325.
39	Burgans Ranch Deposit		32	12	10	MD	Magnesite	Undeveloped. Bradley, W. W., 25, p. 91.
	Creon: see Battenburg							
40	Cummings Deposit		23	11	11	MD		Undeveloped. Aubury, L. E. 06, p. 332.
	Eckert Ranch: see Yordi Ranch							
	Gillian Creek Deposit: see Madeira Deposit							
	Healdsburg Marble Company: see Madeira Deposit							
	Kolling Deposit: see Battenburg Refractory Magnesite Mine							
41	Madeira Deposit		SW¼, 31	9	10	MD	Magnesite	Undeveloped. Bradley, W. W., 25, p. 91.

Magnesite—Continued

Number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B & M		
42	Meeker Ranch Deposit		2, 3	8	11	MD	Magnesite	Undeveloped. Bradley, W. W. 25, pp. 91-92.
43	Norton Ranch			10	10	MD	Magnesite	Small tonnage mined prior to 1910.* Bradley, W. W. 16, p. 327.
	Red Slide Deposit: see Sonoma Magnesite Co.							
44	Sonoma Magnesite Company		6, 7, 8, 17, 20	9	11	MD		Mined prior: or to 1921. Bradley, W. W. 25, pp. 92-96.
	Sotoyome Magnesite Company: see Norton Ranch							
45	Western Carbonic Acid Gas Company		6	8	10	MD	Magnesite	Mined prior to 1918. Bradley, W. W. 25, pp. 96-97.
46	Yordi Ranch		20	11	10	MD	Magnesite	Mined prior to 1912. Bradley, W. W. 25, p. 92.

* Not shown on map.

Manganese

Number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B & M		
47	Aho Mine	Hilma K. Aho, Fort Ross	15, 16	8	12	MD	Manganese	Last mined in 1944. Laizure, C. McK. 26, p. 338.
	Archambeau: see Lucky Strike							
48	Baker Ranch	Mrs. Harry Baker	31	11	8	MD	Manganese	Undeveloped prospect.
	Big Bluff: see Warner							
	Boyer: see Shanks & Copps Lease							
49	Dillon and Seefeldt	Mrs. Dillon, H. Seefeldt	--------	9	14	MD	Manganese	Very small production prior to 1920.*
50	Dreamland	J. H. Rowan	6	8	8	MD	Manganese	Very small production prior to 1920.
	Drum: see Aho Mine							
51	Foerchler	G. A. Foerchler	34	8	7	MD	Manganese	Undeveloped prospect.
52	Foss Ranch	C. C. Foss	19	11	8	MD	Manganese	Undeveloped prospect. Laizure, C. McK. 26, p. 338.
53	Hayden	J. E. Hayden	7	8	12	MD	Manganese	Undeveloped prospect. Laizure, C. McK. 26, p. 338.
54	Holst-Weeks	Frank Weeks	1	7	7	MD	Manganese	Undeveloped prospect.
55	Lucky Strike	W. Archambeau	24	11	9	MD	Manganese	Undeveloped prospect.
56	McDonald	Henry McDonald, Pine Flat	9	10	8	MD	Manganese	Undeveloped prospect.

Manganese—Continued

Number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B & M		
57	Murphy Ranch	Joseph Moreda, Chileno Valley Road, Petaluma	3	4	8	MD	Manganese	Small prospect.
	O'Connell: see Skaggs Springs							
58	Pine Flat	W. J. McLean, C. F. Clark, Calistoga	9, 10	10	8	MD	Manganese	Undeveloped prospect. Bradley, W. W., 18, p. 82.
	Seefeldt: see Dillon and Seefeldt							
59	Shanks & Copps Lease	S. R. Boyer	31	10	10	MD	Manganese	Mined prior to 1920. Laizure, C. McK, 26, p. 338.
60	Sharp	Newton Sharp	7	8	7	MD	Manganese	Undeveloped prospect.
61	Skaggs Springs	P. L. Curtis	SE¼, 13	10	11	MD	Manganese	Undeveloped prospect. Bradley, W. W. 18, p. 83.
62	Warner	Paul Warner	SE¼, 10	10	8	MD	Manganese	Undeveloped prospect.
	Weeks: see Holst-Weeks							
63	Wheeler prospect	----------	20	10	8	MD	Manganese	Undeveloped prospect. Bradley, W. W. 18, p. 83.
64	White-O-Ranch	J. L. McEachem	8	8	9	MD	----------	Oxide stains.
65	Wright	George Wright	7	11	10	MD	----------	Undeveloped prospect.

* Not shown on map.

Perlite

Number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B & M		
66	Annadel Farm	J. J. Cooney	15	7	7	MD (proj.)		Undeveloped.
67	Annadel Farm	J. J. Cooney	26	7	7	MD (proj.)		Undeveloped.
68	Frazier Deposit	A. W. Frazier, Trinity Rd.	1	6	6	MD		Undeveloped.
69	Frazier Deposit	A. W. Frazier, Trinity Rd.	11	6	6	MD		Undeveloped.
70	Quinlan Deposit	C. M. K. Quinlan, Santa Rosa	NE¼, 7	6	7	MD		Undeveloped.

Quicksilver

Number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B & M		
	Abbey: see Crystal Mine							
	Albian: see Cloverdale Mine							
71	Almaden, Incandescent and Tunnel Site Group		31, 32	11	8	MD	Quicksilver	Forstner, Wm. 03, p. 97.
72	Altamont Copper Group	Florence M. Button, Camp Meeker	17	7	10	MD	Quicksilver	Bradley, W. W. 18a, p. 182.
	Amazon: see Kissack Prospect							
73	Anne Belcher Mine	John D. Grant, Healdsburg	4	10	8	MD	Quicksilver	Bailey, E. H. 46, p. 228.
74	Bacon Consolidated Group		11, 12	10	8	MD	Quicksilver	Forstner, Wm. 03, p. 97.
	Big Chief: see Kissack Prospect							
	Big Red: see Dewey's Mine							
	Big Squaw: see Kissack Prospect							
75	Black Bear Mine	Black Bear Mining Corp., Cloverdale	22	11	9	MD	Quicksilver	Last production, 1943. Bailey, E. H. 46, pp. 222-223.
76	Boston Group		3, 9, 10	10	8	MD	Quicksilver	Forstner, Wm. 03, p. 97-98.
	Bright Hope Mine: see Esperanza Mine							

77	Buckeye Mine	Carl A. Baumeister, Healdsburg	3, 4	11	9	MD	Quicksilver	Last production, 1944. Bailey, E. H. 46, p. 220.
	Champion: see Cinnabar King Group							
	Cima Workings: see Dewey's Mine							
78	Cinnabar King Group	H. B. Rosenberg, Healdsburg	10, 11	10	8	MD	Quicksilver	Forstner, Wm. 03, p. 98.
79	Cloverdale Mine	Edward Pratti, and others, Cloverdale	NE¼, SW¼, 4	11	9	MD	Quicksilver	Last production, 1943. Bailey, E. H. 46, pp. 219-221; Forstner, Wm. 03, p. 114
	Clyde Mine: see Culver Baer Mine							
80	Contact Mine	Forrest Riley, Box 955, Corcoran	NW¼, NW¼, 5	10	8	MD	Quicksilver	Last production, 1942. Bailey, E. H. 46, pp. 226-227.
	Crown Point Mining Co.: see Contact Mine							
81	Crystal Mine	H. A. Samson, Healdsburg	5, 6	10	8	MD	Quicksilver	Bailey, E. H. 46, p. 228; Bradley, W. W. 18a, p. 192.
82	Culver-Baer	Culver-Baer Mining Co., Cloverdale	23, 24, 25	11	9	MD	Quicksilver	Last production, 1947. Bailey, E. H. 46, pp. 223-224; Bradley, W. W. 18a, pp. 185-186.
83	Denver and Hope Mines	John D. Grant, Healdsburg	NW¼, 4	10	8	MD	Quicksilver	Bailey, E. H. 46, p. 229.
84	Dewey's Mine	Frank A. Dewey, Cloverdale	NW¼, SE¼, 14	11	9	MD	Quicksilver	Active in 1948. Bailey, E. H. 46, p. 222.
	Diamond: see Lookout Group							
	Double Star: see Jumbo Mine							

Quicksilver—Continued

Number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B & M		
	Eagle Rock: see Dewey's Mine							
	Earlene: see Boston Group							
	Edith: see Bacon Cons. Group							
85	Esperanza Mine	J. G. Cortelyou, 4168 Udal St., San Diego 7	SE¼, 10	11	9	MD	Quicksilver	Last production, 1947. Bailey, E. H. 46, p. 222; Bradley, W. W., 16, pp. 343-344.
86	Eureka Mine	F. M. White, 3248 Encinal Ave., Alameda	32	11	8	MD	Quicksilver	Last production, 1916. Forstner, Wm. 03, pp. 106-108; Bailey, E. H. 46, p. 225.
	Flagstaff: see Eureka Mine							
	Geyser: see Culver-Baer Mine							
	Geysers Mine: see Dewey's Mine							
	Golden Gate: see Bacon Cons. Group							
	Goodenough: see Cinnabar King Group							
87	Great Eastern Mine (includes Mount Jackson Mine and Roaring Lion Prospect)	Sonoma Quicksilver Mines, Inc., 58 Sutter St., San Francisco	NW¼, NW¼, 16	8	10	MD	Quicksilver	Active. Myers, W. B. 48, pp. 253-277.
88	Great Northern		4	10	8	MD	Quicksilver	Forstner, Wm. 03, pp. 108-112.

	Helen: see Cinnabar King Group							
	Hope: see Boston Group							
89	Hurley Prospect		4, 5	10	8	MD	Quicksilver	Forstner, Wm. 03, p. 112.
	Incandescent: see Almaden, Incandescent and Tunnel Site Group							
90	Jumbo Mine	J. G. Cortelyou, Cloverdale	SE¼, 3, NE¼, 10	10	8	MD	Quicksilver	Last production, 1939. Forstner, Wm. 03, pp. 105-106; Bailey, E. H. 46, p. 229.
	Kentuck (Kentucky): see Black Bear Mine							
91	Kissack Prospect	L. D. Kissack, Cloverdale	SE¼, 4	11	9	MD	Quicksilver	Last production, 1945. Bailey, E. H. 46, p. 221.
92	Last Chance	Banner Zeek, Healdsburg	NE¼, 5	10	8	MD	Quicksilver	Bailey, E. H. 46, pp. 228-229.
93	Lookout Group		32	11	8	MD	Quicksilver	Last production, 1902. Forstner, Wm. 03, p. 113.
	Lost Ledge: see Culver-Baer Mine							
	Lucky Stone: see Anne Belcher Mine							
	Manzanita: see Cloverdale Mine							
94	Maricoma Mine		36	10	8	MD	Quicksilver	Forstner, Wm. 03, p. 113*.
	Mattole: see Cloverdale Mine							
	Maud: see Bacon Cons. Group							

Quicksilver—Continued

Number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B & M		
	Mercury: see Cloverdale Mine							
	Missouri: see Culver-Baer Mine							
	Mount Jackson: see Great Eastern							
	Mount Vernon: see Buckeye Mine							
95	Napa Mine		11	10	8	MD	Quicksilver	Forstner, Wm. 03, p. 113.
	Oakland: see Culver-Baer Mine							
96	Occidental and Healdsburg Group		NW¼, 11	10	8	MD	Quicksilver	Forstner, Wm. 03, p. 113.
97	Old Chapman Mine		25 30	10 10	9 8	MD MD	 Quicksilver	 Forstner, Wm. 03, p. 114.
	Pacific Group: see Crystal Mine							
	Paymaster: see Cinnabar King Group							
	Philadelphia: see Cloverdale Mine							
	Pioneer: see Socrates							
	Queen Group: see Contact Mine							

98	Rattlesnake Mine		31	11	8	MD	Quicksilver	Last production, 1919. Bailey, E. H., 46, pp. 224-225.
	Red Cloud: see Crystal Mine							
	Roaring Lion Prospect: see Great Eastern Mine							
99	Skaggs Mine	Leo Curtis, Skaggs Springs	23, 24, 25, 26, 19, 30	10 10	11 10	MD	Quicksilver	Last production, 1943. Ransome, A. L. 39, pp. 469-470.
100	Socrates Mine	Helen Dillingham, Frances Vought	32, 33	11	8	MD	Quicksilver	Last production, 1944. Bailey, E. H. 46, pp. 255, 226.
101	Sonoma Group		5	10	8	MD	Quicksilver	Last production, 1939. Bailey, E. H. 46, p. 228. Bradley, W. W., 18a, pp. 191, 192.
	Squaw: see Kissack prospect							
	St. George: see Bacon Cons. Group							
	Sunrise: see Cloverdale Mine							
	Tunnel Site: see Almaden, Incandescent and Tunnel Site Group							
	Walker Mine: see Contact Mine							
102	Walker Prospect	Meeker Estate, Camp Meeker	8	8	10	MD	Quicksilver	Forstner, Wm. 03, p. 116.
103	Wall Springs		30	8	9	MD	Quicksilver	Forstner, Wm. 03, p. 117.
	Waterloo: see Cloverdale Mine							
	Wild Hog: see Dewey's Mine							
104	Yellowjacket Mine	G. P. Dyer (?)	9	9	7	MD	Quicksilver	Bailey, E. H. 46, p. 230.
105	Young Denver Mine	Banner Zeek, Healdsburg	NE¼, 5	10	8	MD	Quicksilver	Bailey, E. H. 46, pp. 228-229.

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* Not shown on map.

Sand and gravel

Number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B & M		
106	Basalt Rock Co.	Basalt Rock Co., 8th Street, Napa	NE¼, 28	9	9	MD (proj.)	Sand, gravel, crushed stone	Loading, washing, and crushing equipment
107	Dry Creek Gravel Company	James Cuneo, Healdsburg	NW¼, 29	9	9	MD (proj.)	Sand, gravel, crushed rock	Loading, washing, and crushing equipment
108	Harvey Taylor Gravel Company	Harvey Taylor, 103 1st Street, Healdsburg	SE¼, 20	9	9	MD (proj.)	Sand and gravel, crushed rock	Loading and crushing equipment.
109	Hein Bros. Basalt Rock Co.	Hein Bros. Basalt Rock Co., Box 162, Petaluma	NE¼, 16	8	9	MD (proj.)	Sand and gravel	Loading and washing equipment.
110	Maxwell Brothers	W. Carter Maxwell, 928 Sonoma Ave., Santa Rosa	29	8	9	MD	Sand and gravel, crushed rock	Loading, washing, and crushing equipment
111	Mirabel Sand & Gravel Company	Simon Camgros, San Rafael	NW¼, 31	8	9	MD	Sand and gravel	Loading and washing equipment.
112	Onsrud	Onsrud Construction Company, 4606 Sonoma Ave., Santa Rosa	18	7	7	MD (proj.)	Sand and gravel	Idle.
113	Palmer	C. E. Palmer	30	5	5	MD (proj.)	Sand and gravel	Loading equipment.
114	Serres	J. P. Serres, Aqua Caliente	35	6	6	MD (proj.)	Sand and gravel	Idle.
115	Siri and King Gravel Plant	Siri and King, Box 361, Guerneville	NW¼, SW¼, 7	7	10	MD	Sand and gravel, crushed rock	Loading and crushing equipment.
116	Spaletta Gravel Pit	Joseph & DePaul, Box 369, Santa Rosa	18	7	7	MD (proj.)	Sand and gravel, crushed rock	Loading and crushing equipment.
117	Wrobel Pit	L. J. Wrobel, Sonoma, Calif.	13	5	6	MD (proj.)	Sand and gravel, crushed rock	Loading, washing, and crushing equipment.

Crushed and broken stone

Number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B & M		
118	Bloomfield Quarry	J. M. Mattos, Bloomfield	27	6	9	MD (proj.)		
119	Burl Howell Quarry	B. H. Howell, Rt. 1, Box 262, Sebastopol	10	7	10	MD		
120	Cambou Quarry	John Cambou, 6501 Bennett Valley Road, Santa Rosa	34	7	7	MD		
121	Cannon Quarry	L. L. Cannon, 6825 Petaluma Hill Road, Santa Rosa	NE¼, NW¼, 26	5	6	MD (proj.)		
122	Clar Quarry	Siri & King, Box 361, Guerneville	NW¼, SE¼, 32	8	10	MD		Equipped to load.
123	Clark Quarry	Orville Clark, Box 23, Occidental	NW¼, SE¼, 34	7	10	MD		Equipped to load.
124	Dinucci Quarry	Sam Dinucci	NW¼, NW¼, 7	7	9	MD (proj.)		Equipped to load.
125	Fairville Quarry		17	4	5	MD (proj.)		Idle.
126	Felder Ranch Quarry	Leo Felder, Box 248, Sonoma	9	5	6	MD (proj.)		
127	Foppiano Quarry	Andrew Foppiano, R. R. 1, Box 12, Healdsburg	20	9	9	MD (proj.)		
128	Geyser Quarry	Dr. A. D. Resler, Cloverdale	13	11	9	MD		

Crushed and broken stone—Continued

Number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B & M		
129	Gonnella Quarry	B. H. Gonnella, Rt. 4, Box 456, Occidental	SE¼, NW¼, 34	7	10	MD		Equipped to load.
130	Hashagen Quarry	J. M. Hashagen, 118 South State, Ukiah	32	12	10	MD		
131	Hein Bros. Basalt Rock Co.	Hein Bros. Basalt Rock Co., Box 162, Petaluma	3	4	7	MD		Crushed stone; equipped to load.
132	Joulie Quarry	F. B. Joulie, RFD, Glen Ellen	NE¼, NE¼, 10	6	6	MD		
133	Malnati Quarry	Charles Malnati	17	4	7	MD		
134	Meachim Hill Quarry	E. H. & M. F. Maggard	12	5	8	MD		
135	O'Connor Quarry	Robert O'Connor	11	7	8	MD		
136	Onsrud Quarry	Peter Onsrud and Carl Sullivan	11	7	8	MD		
137	Petaluma Hill Road	Lewis Zamoroni, 3015 Petaluma Hill Rd., Santa Rosa	SW¼, 36	7	8	MD (proj.)		
138	Pleasant Avenue Quarry	W. F. Chisolm, 385 Pleasant Ave., Windsor	NE¼, 18	8	8	MD		
139	Stony Point Quarry	W. A. Wilson, Star Route, Box 59, Petaluma	SW¼, 34	6	8	MD (proj.)		
140	Williams' Quarry	F. B. Williams	3	6	7	MD		
141	Zaney Gravels Quarry	Arthur B. Siri, Inc., 1357 Cleavland Ave., Santa Rosa	NW¼, 7	6	7	MD (proj.)		

Stone products unspecified
(Sand, gravel, broken stone)

Number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B & M		
142	Bliss Creek	Jack Corry, Rt. 3, Box 410, Petaluma	25	5	7	MD (proj.)		
143	Cannon Lane	J. S. Cardoza, Jr., Rt. 3, Box 469, Petaluma	10	4	6	MD (proj.)		
144	Fowler Creek	Victor Levroni, Box 557, Sonoma	13, 14	5	6	MD (proj.)		
145	Geyser Road	Robert Woodville, Geyserville	11, 13	10	9	MD		
146	Grace Brothers, Inc.	Grace Brothers, Inc., Box 412, Santa Rosa	2	9	9	MD		
147	Mark West Creek	Russell Denner, 4390 Woolsey Road, Santa Rosa	11	7	9	MD		
148	Mill Creek Road	C. H. Rickman, Rt. 1, Box V-3, Healdsburg	NW¼, NW¼, 30	9	9	MD		
149	Parker Hill Ranch	Errol MacBoyle, Box 398, Santa Rosa	3, 10	7	8	MD (proj.)		
150	Pine Flat Road	Mrs. Abar McCord, Rt. 2, Box 2, Healdsburg	8	10	8	MD		
151	Porter Creek Road	Joe Muligani, Jr., 730 Aston Ave., Santa Rosa	8	8	7	MD		
152	Pronini Ranch	Charles Pronini, Old Adobe Road, Petaluma	15	5	7	MD (proj.)		

Stone products unspecified—Continued

Number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B & M		
153	Sartori Ranch	A. Sartori, Rt. 3, Box 475, Petaluma	34	5	5	MD (proj.)		
154	Sonoma Grove	A. L. Bianchini, Sonoma Grove, Sonoma	12	5	6	MD (proj.)		
155	Willow Creek	E. R. Brown, Jenner	20	7	11	MD (proj.)		

"Flagstones" and colored building stone

Number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B & M		
156	Candy Rock Quarry	V. O. Campbell	3	6	6	MD (proj.)		Colored building stone.
157	Gerberding Quarry	Richard Pittock, lessee	10	6	6	MD (proj.)		Flagstones.
158	Gordenker Quarry	Rodney Gordenker, lessee, FFD 112-A, Glen Ellen	26	7	7	MD (proj.)		Flagstones and colored building stone.
159	Johnson Quarry	William Youngman	10	6	6	MD		Flagstones.
160	Rainbow Quarry	John Sitenga, P. O. Box 195, Verano, California	36	6	6	MD		Flagstones and colored building stone.
161	Valley of the Moon Quarry	S. Cabrol, R. J. Johns, lessee	10	6	6	MD		Flagstones.

Petroleum

No.	Name	Owner	Location				Product	Remarks
			Section	T.	R.	B & M		
162	Petaluma Community—5 No. 2	Trico Gas and Oil Co.	NE¼, Sec. 30	5	6	MD (proj.)	Oil	
163	Petaluma Community—5 No. 3	Trico Gas and Oil Co.	NE¼, Sec. 30	5	6	MD (proj.)	Gas	

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ANNUAL REPORT
# of the
STATE MINERALOGIST
CHIEF OF THE DIVISION OF MINES

for the
One-Hundredth Fiscal Year, July 1, 1948 to June 30, 1949
Annual Report required by amended Section 2203,
Public Resources Code *

By Olaf P. Jenkins **

OUTLINE OF REPORT

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* Senate Bill No. 626, Sec. 3, Chapter 1081, amended Section 2203 of Public Resources Code, Division 2, Chapter 2, to read as follows: "The State Mineralogist shall make an annual report to the Director for transmission to the Governor on or before the fifteenth day of September next preceding the regular session of the Legislature."

** State Mineralogist and Chief of the Division of Mines, Department of Natural Resources, State of California.

LETTER OF TRANSMITTAL

General Warren T. Hannum
Director, Department of Natural Resources
Sacramento, California

Sir: I have the honor to transmit herewith for reference to Governor Earl Warren the annual report of the State Mineralogist, Chief of the Division of Mines, for the 100th fiscal year, July 1, 1948 to June 30, 1949.

Heretofore, the State Mineralogist has been required to "make a biennial report to the Governor on or before the fifteenth day of September next preceding the regular session of the Legislature." This requirement, as provided in Section 2203 of the Public Resources Code, has recently been altered by legislative act to read as follows:

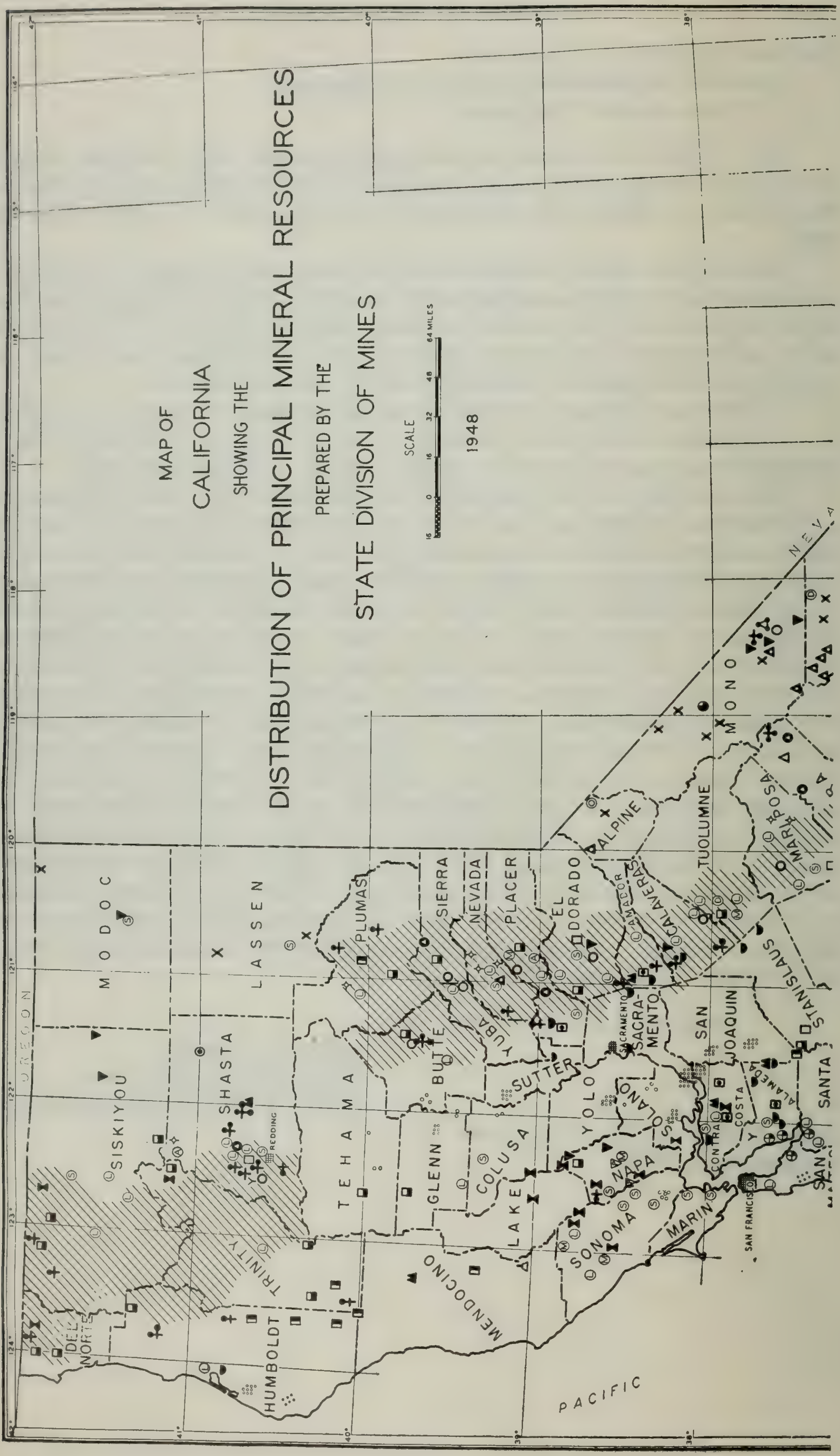
"The State Mineralogist shall make an annual report to the director for transmission to the Governor on or before the fifteenth day of September next preceding the regular session of the Legislature."

The activities of the Division of Mines during the 1948-49 fiscal year are described briefly in this report by the different functional sections which comprise the organization as it is now operating. An attempt has been made to indicate the plans of future work for some years in advance. These plans, however, are subject to modifications as changing economic conditions in the mineral industry may introduce new or different requirements. To keep in step with these requirements and the various requests received from the industry, including chambers of commerce and other organizations interested in the welfare of California, policies and plans are formulated by close cooperation and approval of the State Mining Board. Though new projects may be required from time to time, the most important work is considered to be the fundamental basic and continuing program of accumulating and making available knowledge useful for the enlightenment of the general public and the encouragement of the mineral industry. In so doing, the Division of Mines maintains cooperative programs of work with the federal Geological Survey and Bureau of Mines, and also with the departments of mining and geology of the great universities of the state.

Respectfully submitted,

Olaf P. Jenkins
State Mineralogist and
Chief of the Division of Mines

Ferry Building, San Francisco
September 1, 1949.


MAP OF
CALIFORNIA
SHOWING THE
DISTRIBUTION OF PRINCIPAL MINERAL RESOURCES
PREPARED BY THE
STATE DIVISION OF MINES
SCALE
16 0 16 32 48 64 MILES
1948
OREGON
NEVADA
PACIFIC
DEL NORTE
SISKIYOU
MODOC
SHASTA
REDDING
LASSEN
TRINITY
HUMBOLDT
TEHAMA
PLUMAS
SIERRA
NEVADA
PLACER
BUTTE
YUBA
GLENN
COLUSA
SUTTER
YOLO
LAKE
MENDOCINO
SONOMA
NAPA
SOLANO
MARIN
SAN FRANCISCO
CONTRA COSTA
ALAMEDA
SACRAMENTO
SACRA-MENTO
EL DORADO
AMADOR
ALPINE
CALAVERAS
TUOLUMNE
SAN JOAQUIN
STANISLAUS
MARIPOSA
MONO
SANTA
SAN
124°
123°
122°
121°
120°
119°
118°
117°
116°
115°
114°
42°
41°
40°
39°
38°

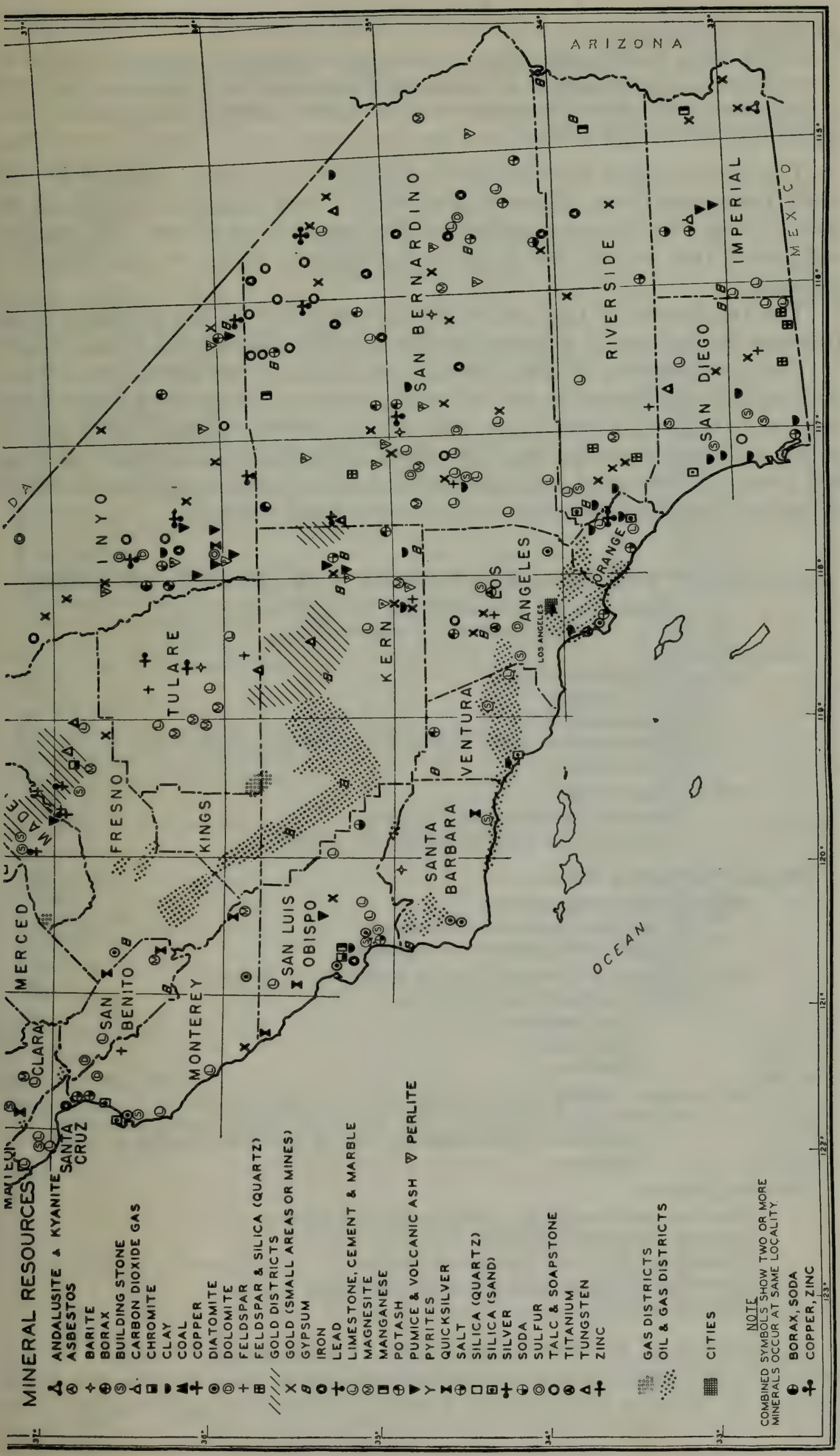

MINERAL RESOURCES
ANDALUSITE & KYANITE
ASBESTOS
BARITE
BORAX
BUILDING STONE
CARBON DIOXIDE GAS
CHROMITE
CLAY
COAL
COPPER
DIATOMITE
DOLOMITE
FELDSPAR
FELDSPAR & SILICA (QUARTZ)
GOLD DISTRICTS
GOLD (SMALL AREAS OR MINES)
GYPSUM
IRON
LEAD
LIMESTONE, CEMENT & MARBLE
MAGNESITE
MANGANESE
POTASH
PUMICE & VOLCANIC ASH
PERLITE
PYRITES
QUICKSILVER
SALT
SILICA (QUARTZ)
SILICA (SAND)
SILVER
SODA
SULFUR
TALC & SOAPSTONE
TITANIUM
TUNGSTEN
ZINC
GAS DISTRICTS
OIL & GAS DISTRICTS
CITIES
NOTE
COMBINED SYMBOLS SHOW TWO OR MORE MINERALS OCCUR AT SAME LOCALITY.
BORAX, SODA
COPPER, ZINC
MATEO
SANTA CRUZ
CLARA
SAN BENITO
MONTEREY
MERCED
MADE
FRESNO
KINGS
TULARE
INYO
DA
SAN LUIS OBISPO
KERN
SANTA BARBARA
VENTURA
LOS ANGELES
LOS ANGELES
ORANGE
SAN BERNARDINO
RIVERSIDE
SAN DIEGO
IMPERIAL
ARIZONA
MEXICO
OCEAN
37°
36°
35°
34°
33°
115°
116°
117°
118°
119°
120°
121°
122°
123°

FIGURE 1.

INTRODUCTION

Public Resources Code:

"2201. The State Mineralogist shall employ competent geologists, field assistants, qualified specialists, and office employees when necessary in the execution of the plans and operations of the division under this chapter and shall fix their compensation."

The functions of the Division of Mines are clearly defined by the Public Resources Code, extracts from which, including the modifications made during the recent session of the State Legislature, are quoted throughout this report when they particularly apply to the function discussed.

The treatment in this report of the activities of the Division is by functions as well as by accomplishments and by plans for future work.

The organization of the Division of Mines is arranged on a functional basis as indicated in the following outline. To carry on these functions, the Division has been supplied with 25 technical employees and 17 clerical and maintenance employees (in addition to the Chief) during fiscal 1948-49. This staff was increased to 27 technical employees and 18 clerical and maintenance employees during fiscal 1949-50.

OUTLINE OF THE ORGANIZATION OF THE DIVISION OF MINES

(Based on its functions and activities as well as upon channels of supervision.)

- Administration
  - Office management section
    - Fiscal control
    - Stenographic pool
    - Maintenance of stock and mailing of publications
    - Guard-Janitor
  - Publications section
    - Editing of technical publications
    - Preparation of bibliographies and indexes
- Mining Engineering Branch
  - Mineral economics section
    - Statistics of mineral production
    - Markets and utilization of minerals
  - Mining operations section (study largely by counties)
    - Including three district offices
      - Los Angeles
      - Sacramento
      - Redding
  - Information section
    - Answering inquiries of the public in person, by telephone, through correspondence, and by providing copies of publications
- Geologic Branch
  - Basic geologic mapping and mineral fuels sections
  - Mineral commodity section
  - Mineral exhibits and laboratory section
  - Geological drafting (illustrations) section
  - Library section

Integration of all these inter-related functions is controlled by the Chief with the assistance of the principal supervisors of the two main branches, the Mining Engineering Branch and the Geologic Branch.

A significant feature of the appropriation for the fiscal year 1948-49 is that it assumes the same amount on a per-capita basis as it did in the year 1890, though the dollar value in 1949 is much less than it was in 1890. Today the appropriation of the Division of Mines amounts to 3.6 cents per person in the state as compared with 3.6 cents per person in 1890.

FINANCIAL STATEMENT

Fiscal 1948-1949 *

Total salaries and wages		$165,464.34
Operating expenses:		
Freight, cartage, & express	$ 1,181.49	
Telephone & telegraph	2,300.00	
Light, heat & power	1,500.00	
Rent of building space	7,720.00	
Rent of equipment	300.00	
Repairs and maintenance of structures & other facilities	8,454.07	
Office supplies & services	3,996.88	
Postage	3,994.81	
Photography supplies & services	787.45	
Blueprinting	446.44	
Printing bulletins & maps	60,000.00	
Printing, general	770.56	
Technical reports	10,200.00	
Auto parts & services	1,925.42	
Auto—gas, oil, tires & tubes	2,890.61	
Travel	9,459.98	
Auto mileage	275.00	
Laboratory supplies & services including assays	3,074.88	
Library supplies & services	984.89	
Exhibits supplies & services	400.30	
Total operating expenses		120,662.78
Equipment:		
Automobile	$6,999.67	
Field	2,199.94	
Laboratory	3,193.89	
Library	1,250.00	
Exhibits	1,763.85	
Office	3,772.57	
Total equipment		19,179.92
Total expenditures		$305,307.04
Special item: Geological exploration in cooperation with U.S. Geological Survey		50,000.00
Grand total		$355,307.04

INFORMATION SERVICE

Public Resources Code:

"2202. The State Mineralogist shall maintain offices, and a museum, library, and laboratory in San Francisco for the purposes provided in this chapter."

"2205. The State Mineralogist shall: . . . (g) Maintain, in effect, a bureau of information concerning the mineral industry of this State . . ."

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* Some of the figures given are approximate, because not all bills for the fiscal year were paid at the time this report was prepared.

Since informing the public is one of the chief functions of the Division of Mines, this service will be found in all sections of the organization.

In the San Francisco office it is estimated that the number of personal interviews rose from 1000 to 1600 per month; telephone calls for information were even greater than that number, making a total of over 40,000 such oral services rendered during the 1948-49 fiscal year. In addition, nearly 22,000 individual pieces of mail were answered; therefore, 62,000 personal services were given. In Los Angeles the total amount was 18,000; in Sacramento, 3600 (not counting telephone calls); and in Redding, 1100 (not counting telephone calls). This would make a grand total of approximately 85,000 personal services, not counting field contacts and talks to public audiences given by various members of the staff.

Occasionally staff members of the Division of Mines are asked to exhibit minerals at public gatherings, and this year collections of gold specimens were shown at six centennial celebrations. Also the use of the Geiger counter with radioactive minerals was demonstrated. Many thousands of persons have viewed these displays during the last fiscal year. As judges to nine county mineral exhibits, members of the staff have given their services during the fiscal year.

The mineral exhibits of the Division of Mines in the Ferry Building have always been popular among adults and children alike. Frequently school teachers bring their classes to the Ferry Building to study the exhibits. For example, in February and March there were 300 children, in April 120, in May 329, in June 239, all of whom viewed the Division of Mines mineral collection.

At numerous times (about 19 during the fiscal year) a member of the staff has shown technical motion pictures to public gatherings where a total of more than 2,000 persons were present. The motion pictures were secured without cost from the U. S. Bureau of Mines and other organizations such as the Signal Oil Company and Richfield Oil Company. Many lectures have been requested, and have been given by staff members who project still pictures. The still pictures are either kodaslides or are made from ordinary photographs that have been taken by staff members while on field trips. The photographs are used for recording information for illustrative publications, as well as for lecture purposes.

In addition to these personal services is the distribution of publications, which is considered even more effective and certainly of greater lasting value than the personal interviews. The publications enable a much larger audience to make use of accurate data prepared in more available form than oral discussions. A publication represents the result of long and careful study by an authority on a particular field or subject.

During 1948 and 1949 the Division of Mines has issued a monthly pamphlet known as *Mineral Information Service,* which releases news concerning the mineral production, resources, and industry of California. It is designed to inform the public of discoveries, operations, markets, statistics, and availability of new technical publications. This pamphlet is distributed without cost but only upon request. The mailing list increased from 4,698 in July, 1948 to 6,846 in July, 1949, which together with personal distribution now requires an issue of 9,000. The list was circularized and verified during the year and will be checked annually in accordance with a recent legislative act.

The Division of Mines prepares and issues mimeographed statements (averaging six a month) for the newspapers, for staff members, or for some particular group, concerning some new legislative act of interest to the mining industry, the announcement of some new publication, or other information which should be released immediately. About 93,000 such mimeographed sheets were distributed during the fiscal year.

Typewritten press releases are occasionally sent to a selected list of newspapers and trade magazines announcing new publications or news items of special interest to the mining public. The publications of the Division are often reviewed in trade magazines and professional journals. Reviews always result in increased sales of the publications.

PUBLICATIONS BY THE DIVISION OF MINES

Public Resources Code:

> "2205. The State Mineralogist shall: . . . (h) Issue from time to time such bulletins as he may deem advisable concerning the statistics and technology of the mineral industries of this State."
>
> "2209. The State Mineralogist may fix a price upon and dispose of to the public all publications of the division, including reports, bulletins, maps, registers, or other publications. The price shall approximate the cost of publication and distribution. He may also furnish the publications of the division to public libraries without cost and may exchange publications with geological surveys, scientific societies, and other like bodies."
>
> "2210. All money received by the division from sales of publications issued by the division shall be deposited at least once each month in the State treasury to the credit of the General Fund . . ."

As an index to the activities and public service of the Division of Mines, no better criterion can be found than its publications. Since 1943 it has issued technical journals and bulletins which occupy 3 feet of book shelving. These reports cover practically the entire field of mineralogy, mineral economics, mining, geology, and related subjects—all of useful knowledge prepared for the enlightenment of the public and encouragement of the mineral industry. Investors, engineers, scientists, educators, and the general public, not only in California but all over the world, have requested such information and depend upon the Division of Mines to give them this service.

The Division's technical publications are sent on exchange to various surveys and provided free to public libraries. Total value of sales of publications since 1943 has amounted to more than $71,000. During the last fiscal year 1948-49, the sales were $22,169.31, an increase of 150 percent over the previous fiscal year. This increase was in part brought about by the unprecedented popularity of one of the bulletins released, and in part by the interest of new industries on the west coast in information concerning the availability of raw mineral products. Bulletin 141, *Geologic Guidebook Along Highway 49—The Mother Lode Country,* sold out 7500 copies in 3 months, and is now in its second edition of 10,000 copies. Other popular bulletins have been those prepared by combining contributions from a large number of authorities, such as Bulletin 118, *Geologic Formations and Economic Development of the Oil and Gas Fields of California;* the *Geologic Map of California;* Bulletin 123, *American Mining Law;* Bulletin 135, *Placer Mining for Gold in California,* and Bulletin 136, *Minerals of California.* It was necessary to reprint Bulletins 118 and 123 this last fiscal year. Bulletin 135 is now out of print and is to be reprinted. Bulletin 136 is a revision of Bulletin 113.

Fiscal year	*Sales of publications*
1947-48	$8,576.24
1948-49	22,169.31

Increase $13,593.07, or about 150 percent.

Since 1945 the Division of Mines has cooperated with the federal Geological Survey on a 50-50 basis, each organization contributing $50,000 per year toward geological work in mineral-bearing areas of the state. Results of this work, and of the work performed by the federal Survey during the war, dealing with California strategic minerals, have been made available in various publications of the Division of Mines.

A cooperative program with the universities of the state has been in effect since 1943. The sum of $10,000 per year has been set aside for purchase of reports (on a nominal basis) from graduate students and faculty members. The results of this work, maps and reports, have been distributed far and wide to the many persons interested in basic geology as related to mineral deposits.

To process and edit carefully all the technical publications of the Division of Mines requires a very high degree of both technical and editorial ability. Since the publications represent the end result of the work of the technical staff and the cooperating agencies of the Division, a special effort has been made to improve greatly all the material which is sent to the press. Besides improvement in quality, there has been an increase in the number of publications processed in the 1948-49 fiscal year in comparison with previous years. In addition to regular quarterly issues of the *Journal,* three older bulletins were reprinted with some revisions, three new bulletins were issued, four were in press, and five were made available for processing. In the year previous, four new bulletins were issued, five were in press, and two were made available for processing.

A by-product of the work of the editorial staff is the bibliographic work. The Division of Mines previously issued Bulletins 104 and 115 which listed all publications on the geology and mineral resources of California from the very inception of its exploration until the end of 1936. It is planned that this work will be supplemented by a bibliography, now in preparation, which will list all publications from 1930 to the end of 1949 or 1950.

Reports published by the Division of Mines appear in two different series: (1) *California Journal of Mines and Geology,* which is a quarterly publication to which subscription is made possible; (2) *Bulletins,* which are issued occasionally as the material for publication becomes available.

The *Bulletin* is used to assemble information of state-wide character, or to cover one unit of a continuous series, for example: Bulletin 144, *Copper in California;* Bulletin 140, *Geology of the Tesla Quadrangle.*

Each issue of the *Journal,* on the other hand, includes several shorter papers, covering special features of some mineral deposit, the use of minerals in some one industry, the mining operations in some one county, recent developments in mining law, and other timely subjects.

Announcements of all these publications are given in the monthly pamphlet *Mineral Information Service.* Here too, new articles pertaining to California, that appear in publications other than those issued by the Division of Mines, are announced. In this way the public is kept informed as to what new material is available for study.

Reports Published by the Division of Mines
Fiscal 1948-1949

SDM—Papers by Division of Mines staff
GS—Papers by U. S. Geological Survey
C—Papers contributed by others
U—Papers by universities

California Journal of Mines and Geology, vol. 44, no. 3, July 1948.
- Unusual Concretions from Templeton, San Luis Obispo County, by R. A. Crippen (SDM)
- Quicksilver Deposits of the Guerneville District, Sonoma County, California, by W. Bradley Myers and Donald L. Everhart (GS, strategic minerals investigation)
- Mining Law in Recent Years, by William E. Colby (C)
- Pumice and Perlite as Industrial Materials in California, by C. R. King (SDM)

California Journal of Mines and Geology, vol. 44, no. 4, October 1948.
- Economic Aspects of Mercury Production in California by Clarence R. King (SDM)
- Current and Recent Mining Activities in the Redding District, by J. C. O'Brien (SDM)
- The Spectrograph and Polarograph, by John Herman (C) Public Resources Code (reprint)
- U. S. Atomic Energy Commission Announces Program to Stimulate Production of Domestic Uranium (reprint)
- Publications of the California State Division of Mines (SDM)
- Index to Volume 44 (SDM)

California Journal of Mines and Geology, vol. 45, no. 1, January 1949.
- Annual Report, Division of Mines, for the Ninety-Ninth Fiscal Year, July 1, 1947 to June 30, 1948, by Olaf P. Jenkins (SDM)
- Quicksilver Deposits of the Oakville District, Napa County, California, by Philip F. Fix and C. Melvin Swinney (GS, strategic minerals investigation)
- Mines and Mineral Resources of Tuolumne County, California, by Clarence A. Logan (SDM)
- Barium, by W. B. Winston (SDM)
- Penn Mine Slag Dump and Mine Water, Calaveras County, California, by Frank J. Wiebelt and Spangler Ricker (reprint)
- Division of Mines Publications Issued September 1, 1948 to November 30, 1948 (SDM)
- Map Symbols Used in Publications of the U. S. Geological Survey (reprint)

California Journal of Mines and Geology, vol. 45, no. 2, April 1949.
- Water-Flooding as a Method of Increasing California Oil Production, Part 1, by Wilbur H. Somerton (U)
- Mineral Resources of Kern County, By W. B. Tucker, R. J. Sampson, and G. Oakeshott (SDM)
- State Geological Surveys, by Wilson M. Laird (reprint)
- Industrial Uses of Limestone and Dolomite, by Oliver Bowles and Nan C. Jensen (reprint)
- An Act for the Development and Control of Atomic Energy (reprint)
- Division of Mines Publications Issued September 1, 1948 to February 15, 1949 (SDM)

Bulletin 118—Oil and Gas (reprint)
Bulletin 123—American Mining Law (reprint)
Bulletin 136—Minerals of California, by Joseph Murdoch and R. W. Webb (U)
Bulletin 140—Geology of the Tesla Quadrangle, California, by Arthur S. Huey (U & C)
Bulletin 141—Geologic Guidebook Along Highway 49—The Mother Lode Country (SDM, U.C.) and reprint.
Bulletin 143—Geology of the Hollister Quadrangle, by N. L. Taliaferro (map only) (U)
Bulletin 144—Copper in California (GS, strategic minerals investigations; U; SDM)

BULLETIN 145—COPPEROPOLIS QUADRANGLE, CALIFORNIA, by N. L. Taliaferro (map only) (U)

BULLETIN 146—LAKE ELSINORE QUADRANGLE, CALIFORNIA, by Rene Engel (map only) (C)

Reports in Press
June 30, 1949

CALIFORNIA JOURNAL OF MINES AND GEOLOGY, vol. 45, no. 3, July 1949.
- Water-Flooding as a Method of Increasing California Oil Production, Part 2, by Wilbur H. Somerton (U)
- Mines and Mineral Resources of Butte County, California, by J. C. O'Brien (SDM)
- Roofing Granules in the Southwest, by Stuart H. Ingram (C)
- The Western Pulp and Paper Industry as a Consumer of Chemicals, by R. G. Mispley (C)
- Mining Law in Recent Years, by William E. Colby (C)
- Ione-Carbondale Clays, Amador County, California, by F. T. Johnson and Spangler Ricker (reprint)

CALIFORNIA JOURNAL OF MINES AND GEOLOGY, vol. 45, no. 4, October 1949.
- Geology of Sonora Limestone Deposit, by George R. Heyl (GS)
- Geology of Gazelle Limestone Deposit, by George R. Heyl (GS)
- Supplement to Bull. 136, *Minerals of California*, by Joseph Murdoch and Robert W. Webb (U)
- Water-Flooding as a Method of Increasing California Oil Production, Part 3, by Wilbur H. Somerton (U)
- Materials of Mineral Origin Used in the Rubber Industry, by Erle C. Zimmerman (C)
- Division of Mines Publications Issued May 1, 1949 to July 31, 1949 (SDM)
- Index to Volume 45 (SDM)
- Supplement—The Elephant as They Saw It, by Elizabeth L. Egenhoff (SDM)

BULLETIN 147—GEOLOGY OF QUIEN SABE QUADRANGLE, CALIFORNIA, by Carlton J. Leith (U)

BULLETIN 148—GEOLOGY OF BLUE LAKE QUADRANGLE, CALIFORNIA, by B. A. Ogle and G. A. Manning (U)

BULLETIN 149—GEOLOGY OF AN AREA NORTH OF SAN FRANCISCO BAY, by Charles E. Weaver (U)

BULLETIN 151—GEOLOGY OF MACDOEL QUADRANGLE, CALIFORNIA
- Geology of the Macdoel Quadrangle, California, by Howel Williams (U)
- Circular Soil Structures in Northeastern California, by Peter H. Masson (U)

Reports Available for Processing for Publication
June 30, 1949

Submarine Phosphate Deposits off California and Mexico, by K. O. Emery and R. S. Dietz (C)

Geology Along the Electra and West Point Tunnels, Amador County, California, by J. H. Wiese, Arvid A. Stromquist, J. H. Eric, and C. M. Swinney (GS)

Geology of the Placerita Oil Field, Los Angeles County, California, by G. B. Oakeshott (SDM)

Geology and Oil Prospects of the San Jose Hills, Los Angeles County, California, by Franklin H. Olmsted (U)

Red Mountain Magnesite Deposit, by A. J. Bodenlos and J. V. Barnes (GS)

Agstone—An Overlooked Geologic Product, by W. D. Keller (C)

Geology of the Corona, Elsinore, and San Luis Rey Quadrangles of Southern California, by E. S. Larsen (U)

Geology of Southwestern Santa Barbara County, by T. W. Dibblee, Jr. (C)

Manganese in California (Supplement to Bulletin 125), by Parker D. Trask (GS, strategic minerals investigation)

Geologic Map and Report on the Neenach Quadrangle, California, by J. H. Wiese (GS)

Old Lime Kilns and Quarries of Marin County, by Adan Treganza (C)

LIBRARY AND ITS SERVICE

Public Resources Code:

> "2205. The State Mineralogist shall: . . .
>
> (d) Provide a library of books, reports, and drawings bearing upon the mineral industries, the sciences of mineralogy and geology, and the arts of mining and metallurgy, such library constituting the library of the division.
>
> (e) Make a collection of models, drawings, and descriptions of the mechanical appliances used in mining and metallurgical processes.
>
> (f) Preserve and so maintain such collections and library as to make them available for reference and examination, and open to public inspection at reasonable hours.
>
> (g) Maintain, in effect, a bureau of information concerning the mineral industry of this State to consist of such collections and library, and arrange, classify, catalogue, and index the data therein contained, in a manner to make the information available to those desiring it."

In the study of any subject or in the preparation of any report on geology, mineralogy, mining, metallurgy, or mineral economics, the initial step may wisely be in the use of the library of the Division of Mines. The library contains over 7800 classified books, not including a like number of volumes of serials, periodicals, federal and out-of-state and foreign government reports and bulletins. This large collection started as a gift to the old State Mining Bureau in 1880. A renewed interest is now being taken in building, maintaining, and operating it for the maximum service to the public and to the staff of the Division of Mines.

People are encouraged to make greater use of the library. Other libraries are encouraged to recognize the value of the Division's publications, which are sent to them regularly as soon as issued. The library is so large that it occupies one main room, the former stock room, a hall, and parts of several other offices, including some space in the district offices. In addition, there is a reading room devoted to trade or industrial magazines and mining periodicals. All these rooms are open for use by the inquiring public. In fiscal 1948-49 there were 1344 visitors to the main library, 1560 to the reading room; 766 were given personal assistance by the librarian. In the previous fiscal year it is estimated that about two-thirds as many persons visited the library.

The library maintains a regular and continuing exchange with other publishing organizations, at present 208 in number. Other exchanges are frequently made, as with the county engineers for their new county maps; 25 such maps have now been secured.

The library controls the mailing of the Division publications to other libraries. There are 147 California libraries and 98 out-of-state and foreign libraries on the list. Some of the larger libraries have several branches, each of which is provided with the Division's publications.

Besides the federal and various state documents, technical books, 139 in number, were acquired by the library through purchase during this fiscal year; by exchange, 12; by donation, 49. Some duplicate volumes of especially needed books were secured for the district offices. Periodicals were secured through subscription, 49 in number; and on exchange, 33. Bulletins, reports, transactions, and miscellaneous books from government agencies, societies, etc., on exchange basis approximated 900 in number.

During the fiscal year, Library of Congress cards were secured for 750 books. In May and June 24 libraries and two museums were visited for the purpose of establishing a better service for the Division's publications in those institutions.

The library is endeavoring to extend and improve its services in the following manner:

(1) To assist the public, especially research or professional persons, in finding published material on various technical subjects.

(2) To assist members of the staff in San Francisco and in the district offices in finding published information for reports they are preparing; to provide duplicate copies of publications for the district offices.

(3) To keep in touch with various libraries in order to be sure that the Division's publications are on display where they can readily be used by the public.

(4) To keep the schools informed as to the subject matter and availability of the Division's publications and to inform them of other sources of information available in the Division's library.

(5) To arrange for showing motion pictures on technical and educational subjects and on conservation of mineral resources; to give illustrated lectures on request; and to inform public gatherings of the services of the Division.

(6) To build the Division's own library, not only through purchase, but by encouraging exchange and donation of books, periodicals, pamphlets, and maps.

(7) To secure sets of important documents which are not already in the library, such as those of the U. S. Bureau of Standards, U. S. Census Bureau, and Carnegie Institute of Washington.

(8) To acquire missing numbers of important periodicals in files which should be completed.

(9) To maintain a collection of drawings and pictures pertaining to the mineral industry with suitable index.

(10) To secure, mount, and maintain a display of up-to-date county maps and other important maps of California which are constantly requested by the public.

(11) To arrange with the State Printing Bureau to bind important periodicals and to repair and rebind worn books.

(12) To secure adequate space and bookcases for the library and to improve its general appearance.

(13) To secure Library of Congress cards for the purpose of cataloging the library.

(14) To arrange the books conveniently and to label the shelves; also to provide users of the library with a diagram of its arrangement.

Books Added to the Library During the 100th Fiscal Year

(D-Donation; E-Exchange)

1. (E) Academy of Natural Sciences of Philadelphia, Proceedings, vol. 100, Academy of Natural Sciences of Philadelphia, 1948.
2. (D) Allen, E. T. and Day, Arthur L., Steam wells and other thermal activity at "The Geysers" California, Carnegie Institution of Washington, Publication 378, 1927.
3. American Association of Petroleum Geologists Bulletin, vol. 12, 1928.
4. (D) American Institute of Mining and Metallurgical Engineers, A brief history of the science of metals, 1948.

5. (D) American Institute of Mining and Metallurgical Engineers, Nonferrous melting practice, 1946.
6. (D) American Institute of Mining and Metallurgical Engineers, General alphabetical and analytical index of American Institute of Mining and Metallurgical Engineers, Transactions, vol. 36-55, 1905-16, 1918.
7. American Institute of Mining and Metallurgical Engineers, Transactions, A. I. M. E. Petroleum Division, vol. 155 and 166 combined. Reprinted, 1944.
8. (D) American Institute of Mining and Metallurgical Engineers, Transactions, Petroleum Division, vol. 160, 1945.
9. (D) American Institute of Mining and Metallurgical Engineers, Transactions, Petroleum Division, vol. 165, 1946.
10. (D) American Institute of Mining and Metallurgical Engineers, Transactions, vol. 166, Metals Division, 1946.
11. (D) American Institute of Mining and Metallurgical Engineers, Transactions, vol. 170, Petroleum development and technology, 1947.
12. (D) American Institute of Mining and Metallurgical Engineers, Transactions, (vol. 170A), Statistics of oil and gas development and production 1946, 1947.
13. (D) American Institute of Mining and Metallurgical Engineers, Transactions, vol. 171, Metals Division, 1947.
14. (D) American Institute of Mining and Metallurgical Engineers, Transactions, vol. 172, Iron and Steel Division, 1948.
15. (D) American Institute of Mining and Metallurgical Engineers, Transactions, vol. 173, Metals Division, 1947.
16. (D) American Institute of Mining and Metallurgical Engineers, Transactions, vol. 174, Petroleum Division, 1948.
17. (D) American Society for Metals, Metals handbook, 1948.
18. American Society for Testing Materials, ASTM standards on mineral aggregates, concrete, and nonbituminous highway materials, 1948.
19. American Society for Testing Materials, Symposium on Mineral Aggregates, Special Technical Publication No. 83, 1948.
20. (E) Annual reviews of petroleum technology, vol. 6, Institute of Petroleum, 1946.
21. (D) Beauchamp, Marshall, California Almanac and State fact book, 1948-49, California Almanac Company, 1947. (3 copies)
22. (D) Beetle, Clara, A. L. A. cataloging rules for author and title entries, American Library Association, 1949.
23. Bennison, E. W. Ground water, its development, uses, and conservation, E. E. Johnson, St. Paul, 1947.
24. Benson, W. N., The tectonic conditions accompanying the intrusion of basic and ultrabasic igneous rocks. U. S. National Academy of Science, vol. 19, 1927.
25. Beringer, Bernard, Underground practice in mining, 3rd ed. Mining Publications Limited, 1947.
26. Borthwick, J. D., Three years in California, with index and foreword by Joseph A. Sullivan, Biobooks, Oakland, 1948.
27. Breed, Chas. B. and Hosmer, G. L., Principles and practice of surveying, vol. 1, 8th ed., John Wiley and Sons, 1945.
28. Breed, Chas. B. and Hosmer, G. L., Principles and practice of surveying, vol. 2, 6th ed., John Wiley and Sons, 1947.
29. (D) Campbell, Robert F., The history of basic metals price controls in World War II, Columbia University Press, 1948.
30. Canadian Institute of Mining and Metallurgy and The Mining Society of Nova Scotia, Transactions, vol. 50, 1947.
31. Caughey, John Walton, Gold is the cornerstone, University of California Press, 1948.
32. (D) Ceramic data book with catalogs, 1948-49. Indust. Publications, Inc.
33. Chalfant, W. A., Death Valley, the facts, 3rd ed., Stanford University Press, 1936.
34. Colton, Walter, The California diary : foreword by Joseph A. Sullivan, Biobooks, Oakland, 1948.
35. Cotton, C. A., Geomorphology, 4th ed., John Wiley and Sons, 1945.
36. Croneis, Carey and Krumbein, Wm. C., Down to earth, an introduction to geology, University of Chicago Press, 1936.
37. (D) Davis, H. P., Gold rush days in Nevada City, Berlinger & McGinnis, 1948.

38. (D) Day, Arthur L. and Allen, E. T., The volcanic activity and hot springs of Lassen Peak, Carnegie Institution of Washington Publication 360, 1925.
39. DeMent, Jack and Dake, H. C., Handbook of uranium minerals, 2nd ed., Mineralogist Publishing Co., Portland, Oregon, 1948. (2 copies)
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43. Edwards, A. B., Textures of the ore minerals and their significance, Australasian Institute of Mining and Metallurgy, Melbourne, 1947.
44. (D) Egloff, Gustav, and Hulla, George, Alkylation of Alkanes, vol. 1: Patents on alkylation of alkanes. (American Chemical Society Monograph series), Reinhold Press, 1948.
45. Emmons, R. C., The universal stage (with five axes of rotation), Geological Society American Memoir 8, 1943.
46. Emmons, William H., The principles of economic geology, 2nd ed., McGraw Hill Book Co., 1940.
47. Engineering index, 1947, Engineering Index, Inc., 1948.
64. Engineering index, 1948, Engineering Index, Inc., 1949.
65. Feigl, Fritz, Qualitative analysis by spot tests. Inorganic and organic applications, Elsevier Publishing Company, 1946.
66. Ferguson, Charles D., California gold fields, Biobooks, Oakland, 1948.
67. Fernald, J. C., Funk & Wagnalls standard handbook of synonyms, antonyms, and prepositions, Funk and Wagnalls, 1947.
68. Flagg, John F., Organic reagents used in gravimetric and volumetric analysis (vol. IV of Chemical analysis) Interscience Publishing Company, 1948.
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72. Goodman, Clark, ed., The science and engineering of nuclear power, vol. 1, Addision-Wesley Press, Cambridge, 1947.
73. (D) Grabau, Amadeus W., Principles of stratigraphy, 3rd ed. A. G. Seiler, 1932.
74. (D) Greenly, Edward and Williams, Howell, Methods in geological surveying, Thomas Murby, London, 1930.
75. Gudde, Erwin G., California place names, a geographical dictionary, University of California Press, 1949.
76. Hall, F. P. and Insley, Herbert, Phase diagrams for ceramists, American Ceramic Society, 1947.
77. Hansen, Howard J., ed., Timber engineers handbook, John Wiley and Sons, 1948.
78. (D) Harker, Alfred, The natural history of igneous rocks, Macmillan, 1909.
79. Himus, Godfrey W., The elements of fuel technology, Leonard Hill, Ltd., 1947.
80. (D) Hinds, Norman E. A., Contributions to pre-Cambrian geology of western North America. II. Eparchean and epalgonkian intervals. II. Uncompahgran and Beltian deposits. . . . Carnegie Institution of Washington. Publication 463, 1936.
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83. Huebner, Walther, Geology and allied sciences, A thesaurus and a coordination of English and German specific and general terms, Part I, German-English, Veritas Press, 1939.
84. Hutchinson, L. I., Handbook for secretaries, 5th ed., Whittlesey House, 1947.
85. Hutchison, Claude B., ed., California agriculture, University of California Press, 1946.
86. (E) Jaggar, T. A., Origin and development of craters, Geological Society of America, Memoir 21, 1947.

87. (D) Jones, P. J., Petroleum production, vol. III, Oil production by water, Reinhold Publishing Company, 1947.
88. (D) Jones, P. J., Petroleum production, vol. IV, Condensate production and cycling, Reinhold Publishing Company, 1948.
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90. Journal of Geology, vol. 34, University of Chicago Press, 1926.
91. Journal of Geology, vol. 35, University of Chicago Press, 1927.
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100. (E) Larsen, Esper S., Jr., Batholiths and associated rocks of Corona, Elsinore, and San Luis Rey quadrangles of southern California, Geological Society of America, Memoir 29, 1948.
101. (E) Longwell, Chester R., Sedimentary facies in geologic history, Geological Society of America, Memoir 39, 1949.
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MINERAL LABORATORY AND ITS SERVICE

Public Resources Code:

"2202. The State Mineralogist shall maintain offices, and a . . . laboratory in San Francisco for the purposes provided in this chapter."

During the 100th fiscal year, a total of 3167 samples were received and examined in the Division of Mines laboratory. This is an increase of 1241 samples, or 64 percent over that for the 99th fiscal year. Such an increase in the number of samples is due to several factors, among which are prompt and accurate service, good public relations, and improved and expanded laboratory facilities. It is expected that more samples will be submitted during the next fiscal year than were submitted during any of the past fiscal years.

By far the greatest number of requests were for identification and determination of the metallic ore minerals, but there is a constant increase of interest in the nonmetallic minerals, especially in the testing of samples for uranium and radioactive minerals. Portable Geiger counters were placed in the Los Angeles, Sacramento, and Redding offices for testing the possible radioactivity of samples. In spite of this additional service, there is a continuing increase in written queries to the San Francisco office.

With the completion of a new laboratory bult in one of the slips of the Ferry Building, the service of the mineralogy section of the Division of Mines will be greatly improved. There will be three parts of this laboratory: (1) The service laboratory (largely for simple blow-pipe and qualitative analysis), for determination of mineral specimens received from the public; (2) The research laboratory (in large part for physical testing), for use of the staff members in their study of mineral commodities; (3) The microscopic laboratory, for use by staff members in the determination of rocks and nonmetallic minerals which cannot adequately be determined by simple qualitative analysis. In the research laboratory there will be equipment for making spectrographic analysis and for carrying on photographic work. It is planned that laboratory studies will supplement field examination of mineral commodities, now being carried on by members of the staff.

MINERAL EXHIBITS

Public Resources Code:

> "2202. The State Mineralogist shall maintain offices, and a museum . . . in San Francisco for the purposes provided in this chapter."
>
> "2205. The State Mineralogist shall: . . .
>
> (c) Make a collection of typical geological and mineralogical specimens, especially those of economic and commercial importance, such collection constituting the museum of the division.
>
> (e) Make a collection of models, drawings and descriptions of the mechanical appliances used in mining and metallurgical processes."
>
> "2206. The State Mineralogist may prepare a special collection of ores and minerals of California to be sent to or used at any world's fair or exposition in order to display the mineral wealth of the State."

There has been such a constant and increasing demand for the Division to exhibit California's commercial minerals to public gatherings and county fairs that it would be desirable for the Division to acquire a portable mineral case and equip it with suitable specimens. A staff member prepared to lecture on some special subject or to present illustrated material would then be able to supplement it with a collection of minerals showing their modern use in industry. The public and both the producer and user of minerals need enlightenment on these subjects to encourage the development and wise utilization of California's natural resources.

During the past fiscal year, mineral shows and mining conventions were attended by staff members of the Division, where they exhibited gold specimens, demonstrated Geiger counters and their effect on radioactive minerals, distributed the Division's publications, and answered questions of the public.

A total of 15 sets of rocks and minerals were provided to schools throughout California, and many groups of young students were conducted through the museum.

Many specimens were donated to the museum by interested and generous persons. Among these specimens are the following:

Mineral Accessions to the Museum

Public Resources Code:

> "2204. The State Mineralogist may receive on behalf of this State, for the use and benefit of the Division, gifts, bequests, devices, and legacies of real or other property and may use the same in accordance with the wishes of the donors. If no instructions are given by the donors, the State Mineralogist shall manage, use, and dispose of the gifts, bequests, and legacies for the best interests of the Division and in such manner as he may deem proper."

21338 Carnotite (approx. $K_2O \cdot 2UO_3 \cdot V_2O_5 \cdot 5H_2O$) in sandstone. From Island Mesa, Colorado. Donor: Marty Hess, October, 1948.

21339 Carnotite (approx. $K_2O \cdot 2UO_3 \cdot V_2O_5 \cdot 5H_2O$) in secondary calcite. From O'Neal mine, Radium No. 7, Summit Point, Utah. Donor: Marty Hess, October, 1948.

21340 Chrysocolla ($CuSiO_3 \cdot 2H_2O$), hydrous silicate of copper. From Mineral Park, Yavapai County, Arizona. Donor: O. E. Bowen, October, 1948.

21341 Ulexite ($NaCaB_5O_9 \cdot 8H_2O$), hydrous sodium and calcium borate. From Sterling borax mine, Ventura County, California. Donor: O. E. Bowen, October, 1948.

21342 Carnotite (approx. $K_2O \cdot 2UO_3 \cdot V_2O_5 \cdot 5H_2O$) in sandstone. From Island Mesa, Colorado. Donor: Marty Hess, October, 1948.

21343 Halotrichite ($FeSO_4 \cdot Al_2(SO_4)_3 \cdot 22H_2O$), hydrous aluminum and iron sulphate. From El Dorado County, California. Donor: Jeffrey Schweitzer, July 7, 1948.

21344 Ilsemanite (perhaps $Mo_3O_8 \cdot nH_2O$). From Getchell mine. Potosi mining district, Humboldt County, Nevada. Donor: Robert S. Creely, September 1, 1948.

21345 Meteorite (stone). From Plainview, Texas. Exchange. Donor: John H. Schilling, September 23, 1948.

21346 Black Sand (containing Zr, Ta, Cb, Th, etc.). From El Dorado County, California. Donor: L. L. Braidwood, October 8, 1948.

21347 Phosphorite (hydrous tricalcium phosphate with varying amounts of calcium chlorite and fluoride), phosphate rock. From 40-Mile Bank, off coast of southern California. Donor: K. O. Emery, November 4, 1948.

21348 Jasper (SiO_2). From Dos Rios, Mendocino County, California. Donor: Eugene A. Bacchi, November 15, 1948.

21349 Jasper (SiO_2). From Nelson Creek area, Monterey County, California. Donor: R. F. Henley, January 13, 1949.

21350 Dioptase (H_2CuSiO_4) with linarite ($(Pb,Cu)SO_4 \cdot (Pb,Cu)(OH)_2$), and caledonite ($(Pb,Cu)SO_4 \cdot (Pb,Cu)(OH)_2$). From near Baker, San Bernardino County, California. Donor: Earl W. Shaw, January 29, 1949.

21351 Prehnite ($H_2Ca_2Al_2Si_3O_{12}$) with laumontite ($(Ca,Na)Al_{12}\ (Al,Si)_2Si_{26}O_8 \cdot 25H_2O$) and calcite. From Sowerbutt quarry, Prospect Park, New Jersey. Donor: T. Orchard Lisle, February, 1949.

21352 Celestite ($SrSO_4$) and strontianite ($SrCO_3$). From near La Couner, Washington. Donor: Wm. E. Caldwell, February 17, 1949.

21353 Onyx ($CaCO_3$). From Calico Mountains, San Bernardino County, California. Donor: Wm. E. Smith, February 24, 1949.

21354 Eglestonite (Hg_4Cl_2O), mercury oxychloride. From abandoned quicksilver mine, 5 miles west of Palo Alto, San Mateo County, California. Donor: R. F. Henley, March 7, 1949.

21355 Realgar (AsS). From Getchell mine, Potosi mining district, Humboldt County, Nevada. Donor: Robert S. Creely, March 7, 1949.

21356 Gold (Au) in quartz. From Four Hills mine, Sierra County, California. Donor: Perry L. Jones, March 14, 1949.

21357 Wilkeite ($3Ca_3(PO_4)_2 \cdot CaCO_3 + 3Ca_3[(SiO_4)\ (SO_4)] \cdot CaO$) in blue calcite. From Commercial quarry, Crestmore, Riverside County, California. Donor: Robert L. Cooney, April 11, 1949.

21358 Gold (Au) in quartz. From Yanky Jim mine, west of Redding, Shasta County, California. Donor: R. V. Hollister, May 13, 1949.

Renovation of the Museum

Since the space in the museum is now filled with exhibit cases which are overcrowed, antiquated, and poorly constructed, it is difficult to find additional space for new acquisitions received from generous donors.

The appearance of the museum room, however, is being greatly improved by painting and by covering the floor with Accoflor. The old worn wooden floor has always been a fire hazard. New fluorescent lights have been installed. It is further planned to clean the cases, to insert a light-colored monkscloth as a background for the specimens, to check their identification, and to rearrange them on suitable wooden blocks with new labels. An explanatory guide to the museum will be prepared for the public.

The pictures on the walls of the museum will be improved in appearance. Elimination of some of the antiquated material may give some room for exhibiting new illustrations and collections of industrial minerals, arranged to show how these minerals are used in modern industries.

STUDY OF MINERAL ECONOMICS

Public Resources Code: (including recent amendments) :

> "2205. The State Mineralogist shall:
>
> (a) Make, facilitate, and encourage special studies of the mineral resources and mineral industries of the State.
>
> (b) Collect statistics concerning the occurrence and production of the economically important minerals and the methods pursued in making their valuable constituents available for commercial use."
>
> "2207. The owner, lessor, lessee, agent, manager, or other person in charge of any mine of whatever kind or character within the State shall forward to the State Mineralogist, upon his request, at his office, not later than the thirty-first day of March in each year, upon forms which will be furnished, a report showing the character of the mine, the method of working the mine and the general condition thereof, and the total mineral production for the preceding calendar year. Any such person who fails to comply with the provisions of this section is guilty of a misdemeanor.
>
> Such reports shall be confidential. Other records are public records unless excepted by statute. Statistical bulletins based on these reports and published under the provisions of Section 2205 of this code shall be compiled to show, for the State as a whole and separately for each county, the total of each mineral produced therein, provided that, in order not to disclose the production of any operator, no production figure shall be published which represents the production of less than three operators; and when such production figure for any county would conflict with such provision it may be combined with such production figures for one or more other counties. Such bulletin shall be published annually by June 30th or as soon thereafter as practical."

The development of industrial minerals is controlled largely by conditions of economics, and authoritative statistics on mineral production in the state form the background of any study of mineral economics. This information is especially desired by chambers of commerce, and by those who manage or wish to develop new mineral industries.

Final mineral production figures for 1947 were issued by the Division in *Mineral Information Service* of October 1, 1948, and a table of counties with details of their mineral production by substance appeared in the issue of February 1, 1949. In Bulletin 142, *The Counties of California,* a description is given of each county, its geologic features, mineral resources, significant activities in 1947, and production figures by substance for the same year.

A bulletin on mineral production in 1948 featuring a description of each mineral commodity produced in California, its geologic occurrence, mineralogy, localities, utilization, markets, mining methods, treatment, and history of production is to be published during the fiscal year 1949-50.

Statistics on the mineral production of 1947 represent the first to be released under the new cooperative agreement of this Division and the United States Bureau of Mines. Under this agreement the U. S. Bureau sends out all forms to producers asking for information on mineral production, while the Division furnishes names and addresses of new producers. The Division also visits the producers who are delinquent in reporting production and makes an effort to obtain the cooperation of each such producer in complying with the State law in this regard.

The compiled figures, prepared by the federal Bureau, are sent to the Division as totals by substance and by county; also by substance for each county. Where the county contains less than three producers of a mineral substance, figures on that substance are combined with those of other counties to prevent the release of any confidential information.

The cooperative agreement has so far proved to be satisfactory. It avoids duplication of effort between the state Division and the federal Bureau; it results in securing production figures which are accurate and complete, and it avoids the discrepancies which occurred when the two agencies were collecting production figures independently.

Figures for the production of minerals in California the first half of 1949 indicate that the petroleum output decreased slightly in quantity as compared with the same period in 1948. Quotations on crude oil in the period between January 25, 1949, and June 1 decreased as much as $1.00 a barrel on the heavier gravity oil. Increases of as much as $0.20 a barrel on the lighter gravity oils were in effect over the same period. The production of natural gas for the first half of the year indicated a slight increase as compared with the previous 6 months. The portland cement production in the first 5 months of 1949 showed a slight increase over the same period of 1948. The gold production was practically the same in the first part of 1949 as it was in 1948. The silver, lead, and zinc monthly average for the first 5 months of 1949 was up considerably over the 1948 monthly average. Early in June 1949 sharp cuts in the quotations on copper, lead, and zinc were noted, and this may affect production of these metals for the rest of the year. The quicksilver production for the first half of 1949 was approximately half that for the same period of 1948. Only one large quicksilver mine was in operation.

Table 1. California counties in order of total value of recorded mineral production

County	Year of first recorded output	Rank of output in 1948	Value of total output	1948 value of output	Principal minerals in order of total value for 1948
Los Angeles	1880	2	$3,716,492,637	$278,436,293	Petroleum, natural gas gasoline, miscellaneous stone.
Kern	1880	1	2,784,373,500	293,773,122	Petroleum, natural gas gasoline, natural gas.
Orange	1880	4	1,156,481,857	106,472,783	Petroleum, natural gas gasoline, natural gas.
Fresno	1880	3	915,923,503	124,450,502	Petroleum, natural gas, natural gas gasoline.
Ventura	1880	5	713,810,464	87,543,246	Petroleum, natural gas gasoline, natural gas.
San Bernardino	1880	7	554,556,269	44,640,646	Cement, borates, potash, miscellaneous stone.
Santa Barbara	1881	6	466,970,130	60,753,770	Petroleum, diatomite, natural gas gasoline.
Kings	1894	8	333,802,757	36,337,310	Petroleum, natural gas, natural gas gasoline, gypsum.
Nevada	1880	19	246,616,736	3,659,073	Gold, sand and gravel, silver.
Shasta	1880	27	212,114,724	1,680,434	Pyrite, miscellaneous stone, gold, zinc.
Sacramento	1880	9	189,604,528	16,737,925	Natural gas, gold, miscellaneous stone.
Riverside	1891	12	163,592,471	9,269,937	Cement, gypsum, raw clay.
Amador	1880	34	154,801,069	941,126	Clay, gold, miscellaneous stone.
Santa Clara	1850	10	149,295,689	13,317,067	Cement, miscellaneous stone, raw clay.
Calaveras	1880	16	141,376,737	4,662,145	Cement, sand and gravel, gold.
Inyo	1880	11	137,733,244	10,286,796	Lead, tungsten, soda ash, zinc.
Alameda	1880	14	125,321,354	8,771,793	Miscellaneous stone, salt, magnesium compounds.
Yuba	1880	23	116,670,658	2,226,195	Gold, miscellaneous stone, silver.
Santa Cruz	1894	18	107,693,372	4,024,125	Cement, miscellaneous stone.
Solano	1873	13	94,193,792	8,903,771	Natural gas, miscellaneous stone.
Plumas	1880	54	82,505,166	32,975	Gold, miscellaneous stone, silver.
Butte	1880	29	81,070,826	1,284,737	Gold, miscellaneous stone, natural gas.
Contra Costa	1894	30	80,398,599	1,255,576	Miscellaneous stone, natural gas, clay.
San Mateo	1895	15	72,739,960	5,707,031	Cement, miscellaneous stone, magnesium salts.
San Benito	1865	21	66,867,105	2,803,469	Cement, miscellaneous stone, quicksilver.
Placer	1880	37	61,629,670	512,671	Miscellaneous stone, clay, gold.
Tuolumne	1880	36	57,817,532	850,342	Miscellaneous stone, lime, gold.
Sierra	1880	42	54,357,302	384,223	Gold, sand and gravel, lead.
Siskiyou	1880	32	53,653,635	1,012,137	Gold, pumice, miscellaneous stone.
Trinity	1875	44	49,567,545	311,010	Gold, miscellaneous stone, silver.
San Diego	1880	22	49,025,989	2,594,065	Miscellaneous stone, salt, clay.
El Dorado	1880	26	47,745,352	1,758,799	Miscellaneous stone, lime, gold.
Napa	1862	45	45,795,664	303,385	Pumice, miscellaneous stone, mercury.
San Joaquin	1885	20	35,192,376	3,077,835	Miscellaneous stone, natural gas, gold.
Mono	1880	43	33,837,477	355,497	Pumice, pyrophyllite, gold.
Mariposa	1880	46	31,851,839	280,739	Gold, miscellaneous stone, barite.
Merced	1880	35	31,210,128	869,757	Gold, miscellaneous stone, silver.

Monterey	1889	17	27,056,626	4,196,755	Magnesium compounds, miscellaneous stone, salt.
Sonoma	1873	31	23,879,279	1,029,437	Miscellaneous stone, mercury, pumice.
Stanislaus	1880	33	23,421,351	954,234	Miscellaneous stone, gold, natural gas.
Lake	1873	52	21,605,523	116,787	Miscellaneous stone, mercury.
Tulare	1880	24	18,407,839	2,057,745	Natural gas, miscellaneous stone, tungsten.
San Luis Obispo	1876	28	17,110,901	1,428,990	Petroleum, miscellaneous stone, mercury.
Madera	1893	38	16,653,510	446,627	Natural gas, pumice, gold.
Marin	1888	41	15,952,237	389,245	Miscellaneous stone, clay.
Imperial	1907	25	14,787,422	1,957,508	Gypsum, miscellaneous stone, gold.
Humboldt	1880	40	13,396,501	407,996	Miscellaneous stone, natural gas, gold.
San Francisco	1894	—	8,732,104		Miscellaneous stone.
Del Norte	1880	48	6,113,785	186,902	Miscellaneous stone, chromite.
Glenn	1893	47	4,462,797	271,276	Natural gas, miscellaneous stone.
Yolo	1873	50	4,328,698	144,870	Miscellaneous stone, natural gas, mercury.
Colusa	1875	55	4,288,818	20,756	Miscellaneous stone, gold.
Mendocino	1880	39	3,424,581	426,130	Miscellaneous stone.
Lassen	1880	53	2,874,854	38,156	Miscellaneous stone, gold.
Modoc	1880	49	2,226,635	145,490	Pumice, miscellaneous stone, gold.
Tehama	1880	—	1,804,472		Miscellaneous stone.
Sutter	1908	51	1,018,440	130,447	Natural gas, clay, miscellaneous stone.
Alpine	1880	—	370,974		Tungsten concentrates.
Total recorded value by counties—1850-1948 inclusive			$13,648,609,003		
1948 total value				$1,174,674,000	

Table 2. Value of total recorded mineral production by substances to and including 1948

Mineral products in order of total value	Year of first recorded production	Total value to 1948 [f] inclusive	Value of 1948 output [f]	Year of peak value	Year of peak output	Order of principal producing counties in 1948	Remarks
Petroleum	1865	$8,762,620,026	$823,696,000	1948	1948	Kern, Los Angeles, Fresno, Orange	California's output is exceeded only by Texas. The total value of California's petroleum output is greater than the total of all other mineral products.
Gold	1848	2,296,913,366	14,751,555	1852	1852	Sacramento, Nevada, Yuba	California led the nation in output of gold for many years until 1941. During the war most of the mines were closed down. In 1948 California again took the lead in gold production.
Cement	1891	733,772,457	57,742,226	1948	1948	San Bernardino, Santa Clara, Riverside	State's output surpassed only by Pennsylvania.
Natural gas	1888	696,131,314	64,803,000	1948	1948	Los Angeles, Sacramento, Solano, Kern	Output exeeded only by Texas in 1948.
Miscellaneous stone	1893	554,962,764	43,748,419	1948	1948	Los Angeles, Alameda, San Bernardino	Leads the nation in output of sand and gravel, and ranks high with stone.
Copper	1882	198,449,988	208,754	1916	1909	Inyo, Shasta, San Bernardino	Shasta County led from 1897-1918, Plumas County from 1919-1940 and Siskiyou from 1941 to 1944.
Brick and hollow tile	1893	175,032,616	d	1923	----------	Los Angeles, Contra Costa, Sacramento	Approximately half the annual value is for fire brick.
Borates	1864	170,260,917	11,147,735	1947	1947	Kern, San Bernardino, Inyo	Chief source of world's supply.
Quicksilver	1850	148,480,175	855,770	1943	1877	San Benito, Sonoma, San Luis Obispo	Leads the states with 78% of nation's output.
Potash	1914	87,944,792	*	1947	1947	San Bernardino	Second among the states. Total inc. 1947.
Silver	1880	75,043,714	655,954	1921	1921	Inyo, San Bernardino, Nevada.	Is usually a byproduct in mining other metals
Soda (soda ash and salt cake)	1894	[g] 66,480,270	[g] 6,623,280	1948	1948	San Bernardino, Inyo	Leads the nation in output of natural soda.
Salt	1887	52,536,361	3,927,722	1948	1948	Alameda, San Bernardino, San Diego	An important source of national supply.
Diatomite	1889	47,598,524	*	1947	1947	Santa Barbara, Los Angeles	California is the chief source for the nation. Total inc. 1947.
Tungsten ore	1905	45,298,370	*	1943	1943	Inyo, San Bernardino, Tulare	Output was passed by Nevada and North Carolina in 1947.
Mineral water	1887	40,601,881	b	1930	1930	Los Angeles, San Bernardino, Marin	Represents that which is bottled for sale. Total inc. 1946.
Clay (raw)	1887	31,892,359	3,813,329	1948	1948	Kern, Amador, Riverside	Makes California's ceramic industry possible.
Lime	1894	29,954,430	3,026,941	1948	1947	Monterey, El Dorado, San Bernardino	Lime was included with limestone 1941-1946.
Granite	1887	29,585,027	c	1925	----------	San Diego, San Bernardino, Fresno	Cannot compete with concrete construction. Total inc. 1946.
Limestone	1894	26,075,905	c	1946	1946	El Dorado, San Bernardino, Tuolumne	For industrial purposes, not including that for cement. Total to 1946.
Lead	1877	24,753,802	3,261,380	1948	1946	Inyo, San Bernardino, Shasta	Darwin District principal producing area.
Coal	1861	23,400,260	b	1880	1880	Amador, Trinity	Coal from Amador County is mined for its wax content. Total inc. 1946.
Magnesite	1887	19,290,994	*	1917	1917	Santa Clara	Natural mineral is being replaced by magnesia from sea water. Total inc. 1946

Zinc	1906	19,044,970	1,416,450	1945	1926	Inyo, Shasta, San Bernardino	California output is marginal.
Magnesium compounds	1916	18,662,112	2,549,000	1944	1944	San Mateo, Monterey, Alameda	Second among the states.
Gypsum	1887	16,986,955	2,354,390	1948	1948	Imperial, Riverside, Kern	Fourth among the states in 1947.
Pyrite	1898	16,365,248	*	1909	1909	Shasta	Output ranks third among states in 1946.
Chromite	1869	12,946,179	*	1918	1918	Del Norte	California's output was first among the states in 1945.
Talc, soapstone, pyrophyllite	1893	12,853,168	1,773,764	1948	1948	Inyo, San Bernardino, Mono	Second among the states as to value, 1948.
Iron	1881	9,728,121	*	1944	1943	San Bernardino, Riverside	With the construction of the Fontana steel plant in 1942 production showed a marked increase. Total inc. 1947.
Silica	1899	9,410,764	*	1946	1946	San Bernardino, Kern	California is an important source for quartz and glass-sand. Total inc. 1946.
Iodine	1929	7,851,461	*	1946	1946	Los Angeles	Only production in nation. Total inc. 1946.
Paving blocks	1887	5,712,288		1912	1912		Has been replaced with smooth paving.
Pumice and pumicite	1909	5,814,890	$1,110,447	1948	1948	Napa, Siskiyou, Modoc	Leads the nation in output.
Manganese ore	1887	5,124,616		1944	1944		1944 output was surpassed only by Montana and Nevada.
Dolomite	1915	4,971,453	[c]	1946	1943	Monterey, San Benito, Tuolumne	A large percent of the output goes into the reduction of magnesia from sea water. Total inc. 1946.
Sandstone	1887	4,700,255	[c]	1903	1904	Monterey, Napa	Production of dimension stone has decreased in recent years. Total inc. 1946.
Bituminous rock	1887	4,650,320		1888	1910		A possible future source of oil. Total inc. 1946.
Bromine	1926	4,567,266	*	1944	1944	San Bernardino, Alameda	The state is an important source. Total inc. 1946.
Bentonite	1899	3,703,611	[a] 101,450	1928	1928	San Bernardino, Inyo, San Diego	California is an important source of bentonite. Total inc. 1946.
Barite	1910	3,604,813	*	1947	1945	Mariposa	The state is an important source of barite. Total inc. 1947.
Marble	1887	3,587,755	[c]	1909		San Bernardino, San Luis Obispo	Hard to compete with artificial stones. Total inc. 1946.
Gems	1900	2,631,532	[b]	1906		San Diego	Includes optical minerals. Production irregular. Total inc. 1946.
Molybdenum	1916	1,994,483	*	1943	1943	Inyo	Produced as a byproduct of tungsten ore. Total inc. 1946.
Carbon dioxide	1894	1,773,564	[b]	1946	1944	Imperial, Mendocino	State is an important source of natural carbon dioxide. Total inc. 1946.
Calcium chloride	1921	1,754,673	167,610	1926	1926	San Bernardino	Second as to value among the states.
Lithium compounds	1899	1,470,049	*	1946	1920	San Bernardino	California leads the nation. Total inc. 1947.
Slate	1889	1,420,017	*	1906		El Dorado, Inyo, Mariposa	Total inc. 1946.
Platinum metals	1887	1,194,216	*	1922	1941	Sacramento, Yuba, Merced	Output exceeded only by Alaska. Total inc. 1946.
Feldspar	1910	1,067,285	*	1928	1928	San Bernardino, Kern	Total inc. 1946.
Sillimanite group	1922	969,919		1926	1926	Mono, Imperial (in the past)	California production in the past was andalusite and kyanite. Total inc. 1946.
Sulfur	1865	850,334	*	1941	1941	Inyo, Alpine	Production irregular. Total inc. 1947.
Grinding-mill pebbles	1915	358,677	*	1916	1917	San Diego	Output small. Total inc. 1947.
Mineral paint	1890	249,038	[e]	1893	1903	Amador	Output small and irregular. Total inc. 1946.
Antimony	1887	226,936	1,467	1916	1916	Inyo	Output has been intermittent and of little importance.

Table 2. Value of total recorded mineral production by substances to and including 1948—Continued

Mineral products in order of total value	Year of first recorded production	Total value to 1948 [f] inclusive	Value of 1948 output [f]	Year of peak value	Year of peak output	Order of principal producing counties in 1948	Remarks
Strontium	1916	212,258		1941	1941	Imperial, San Bernardino (in the past)	Second in nation in 1946. Total inc. 1946.
Mica	1902	198,574		1947	1947		Most mica mined in California was sericite variety used as ground mica. Total inc. 1947.
Asbestos	1887	170,292	*	1910	1921	Shasta, Placer	Output all of amphibole variety in 1948. Total inc. 1947.
Titanium	1927	165,980	*	1928	1928	Los Angeles	Several occurrences of ilmenite are known in the State. Total inc. 1947.
Onyx and travertine	1887	122,219	[c]	1894			Output irregular. Total inc. 1926.
Shale oil	1922	109,500		1924		Santa Barbara (in the past)	A future source of oil.
Graphite	1901	87,495		1918	1918		No outpu tin recent years.
Tin	1891	62,534		1892	1892		Several occurrences are known in the State. Total inc. 1947.
Serpentine	1895	47,218	[c]	1946	1946	Santa Clara	Is now being used in fertilizers. Total inc. 1946.
Garnet (abrasive)	1938	24,795		1945	1945	Inyo	Byproduct from tungsten ore tailings. Total inc. 1945.
Calcium silicate	1933	23,854		1938	1938		Used in the manufacture of mineral wool.
Cadmium	1917	16,489		1917	1917		Cadmium reported as a byproduct from zinc ores.
Fluorspar	1917	8,912		1944	1944		Output has been intermittent.
Perlite	1947	4,873	*	1948	1948	Napa	First production was included with pumice.
Bismuth	1904	2,400		1904			A bismuth concentrate was made in 1942 but not shipped.
Arsenic	1924	1,356		1924			Production reported only in 1924.
Zircon	1931	1,310		1941			Small amounts of zircon sand found in most black sand
Alum minerals	1938	160		1938		Riverside (in past)	Occurrences of alum minerals have been noted several places in state.
Total value for 1948			$1,174,674,000				
Total recorded value including 1948		$14,534,587,499					

* Figures appear only in total because this substance was reported by less than three operators.

[a] 1948 and 1947 output included with raw clay.

[b] Not canvased by U. S. Bureau of Mines (1947-1948).

[c] 1948 output included with stone.

[d] 1947 and 1948 output included under heavy clay production.

[e] 1948 total included with iron ore.

[f] 1948 and 1947 production figures compiled by U. S. Bureau of Mines. Previous statistics by California State Division of Mines.

[g] Does not include salt cake in 1948.

SURVEY OF MINERAL UTILIZATION AND MARKETS IN CALIFORNIA

As a background for a study of markets for minerals in California, the Division of Mines has started a survey of the utilization of minerals in various industries. This survey is in part carried on by members of the staff and in part contributed by technical persons in the industries. Eventually sufficient information should be accumulated so that the Division will be able to supply information on specifications, prices, and quantities of various minerals used in different industries.

The survey has already resulted in the publication of the following papers in *Mineral Information Service:*

The western pulp and paper industry as a consumer of minerals and inorganic chemicals, by R. G. Mispley of Crown Zellerbach Corp., published on February 1, 1949.

The western paint and varnish industry as a consumer of chemicals, by M. W. Reece and H. L. Wampner of Reichold Chemicals, Inc., published on March 1, 1949.

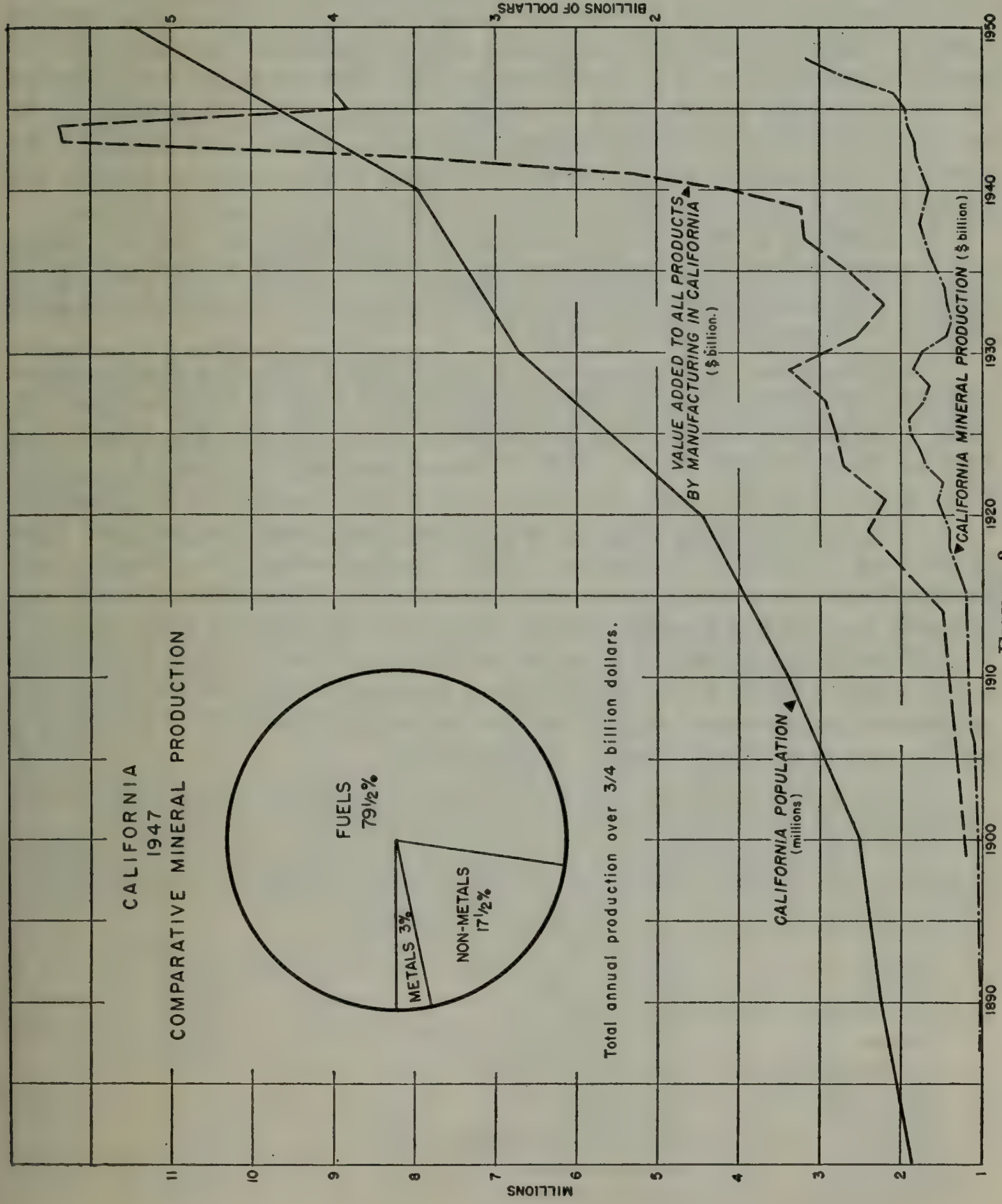


FIGURE 2.

The mineral needs and problems of the ceramic industry, by H. R. Goodrich of Gladding, McBean and Company, published on April 1, 1949.

Gypsum in California, its occurrence and uses, by a staff member, published on May 1, 1949.

Materials of mineral origin used in the rubber industry, by Erle G. Zimmerman of the Firestone Tire and Rubber Company, published on June 1, 1949.

STUDY OF MINING OPERATIONS BY THE DISTRICT OFFICES

Public Resources Code:

> "2208. The State Mineralogist or a qualified assistant may at any time enter or examine any and all mines, quarries, wells, mills, reduction works, refining works, and other mineral properties or working plants in this State in order to gather data to comply with the provisions of this chapter."

To keep abreast of the mining activities and operations in the state, it is necessary that the Division of Mines maintain a continuous program of visiting areas which are active in development work. This work is handled largely by the staff members of the district offices, but also by some of the San Francisco headquarters staff. Results of the work appear for the most part in the form of county reports which are published in the Division's quarterly *California Journal of Mines and Geology.* In abstract form, and by way of news items, some of the material reaches the public by way of the Division's monthly *Mineral Information Service.*

In addition to the county reports on operations, the district offices also contribute to the annual statistical bulletins and to the survey of mineral utilization and markets in California, and are constantly engaged in giving information to the public.

Extensive use of minerals in the industries of the Los Angeles area indicates the desirability of doing more of this type of work in that district. A report on the mineral resources of Kern County was finished in the Los Angeles office in the 1948-49 fiscal year and published in April 1949. Reports on Inyo and San Bernardino Counties are in preparation.

At the Sacramento office, a report on Tuolumne County was completed and published in January 1949. Similar reports on Fresno and Madera Counties were in preparation during the 1948-49 fiscal year, and a report on Amador County will be started in the 1949-50 fiscal year.

At the Redding office a report on current and recent mining activities in the entire district was completed and published in July 1948. A report on Butte County was completed for publication in July 1949, and a similar report on Yolo County was prepared.

In the San Francisco office reports on Sonoma and Alameda Counties were prepared and will be published during the fiscal year 1949-50.

The following outline is a suggested 5-year program for issuing reports on mining operations by counties. The Division's present reports on the counties listed are now at least 10 years old:

County	*Date of last report*	*Proposed new report*
Alpine	October 1931	1954-55
Calaveras	July 1936	1954-55
Colusa	July 1929	1954-55
Contra Costa	January 1927	1950-51
Del Norte	July 1925	
El Dorado	July 1938	1952-53
Glenn	October 1929 (out of print)	1954-55
Kings	October 1930	1950-51
Lassen	October 1936	1953-54

County	*Date of last report*	*Proposed new report*
Los Angeles	July 1937	1951-52
Marin	July 1926	1950-51
Mariposa	April 1928 (out of print)	1951-52
Mendocino	October 1929	1953-54
Merced	April 1925 (out of print)	1952-53
Modoc	October 1936	
Monterey	January 1925	1952-53
Orange	January 1925	1950-51
Placer	January 1936 (gold only)	1953-54
Plumas	April 1937	1951-52
Sacramento	January 1925	1950-51
San Diego	January 1939 (out of print)	1953-54
San Francisco	April 1929	1951-52
San Joaquin	April 1925	1950-51
San Luis Obispo	October 1935	1954-55
San Mateo	April 1929	1951-52
Santa Barbara	October 1925	1952-53
Santa Clara	January 1930	1951-52
Shasta	April 1939	1952-53
Solano	April 1927	1950-51
Sutter	1920 (Report XVII)	1950-51
Tulare	October 1930	1953-54
Ventura	July-October 1932 (out of print)	
Yuba	July 1930 (out of print)	1953-54

This plan, however, is based on a slight increase in the Division's field staff. It is apparent that the work, which should be kept up-to-date, is far from that objective. To satisfy the public demand for up-to-date reports on operations by counties, the Division should have several additional technical field employees.

The Division also plans to issue from time to time, and in advance of the county reports, special descriptions of individual mine operations, where such information might be of special benefit to other operators of similar properties.

GROWTH OF ACTIVITIES IN SOUTHERN CALIFORNIA

As a community grows in population, its markets expand and industries increase, causing greater and greater demand for raw mineral materials which are used in manufacturing the products needed. This is true of the San Francisco Bay area, and is the case in the Los Angeles area, where market activity has stimulated the development of industrial minerals all over the State, but especially within the immediate vicinity of this great population center. As a source for industrial minerals of every conceivable sort, southern California is indeed favorably supplied. The huge market for such new mineral materials which Los Angeles offers is rapidly expanding. For this reason, the public demand for the services of the Division of Mines is constantly increasing. It has been necessary for the San Francisco headquarters staff to supplement the work of that of the Los Angeles district. Even this is not enough, and it is obvious indeed that the Los Angeles district office must eventually become a much larger functional unit than it has been in the past.

In the Los Angeles district office during the past fiscal year, the Division's information services increased 46 percent and the value of publications sold increased 275 percent over the previous year. Many more people use its local library and its small but well-arranged mineral exhibit. The office has not only carried on regular field investigations by its limited staff, but has worked with the Division's cooperating agencies, both federal and university. It has secured cooperation with other agencies, such as counties, private industry, and with the Los Angeles Chamber of Commerce on the study of markets.

It has arranged for special studies on building stone, beach pebble deposits, market studies, and special mining operations, as in the Darwin and Eagle Mountains districts. It has represented the Division and made contributions of service on various occasions at gatherings of professional societies on mining, oil and gas, geology, mineralogy, and educational institutions. Thus, by working in close coordination with the San Francisco headquarters office, the Los Angeles district office has developed into an important branch of this Division, assuming many of its various broader functions in addition to those of studying mining operations in the particular counties of the Los Angeles area.

ORE BUYERS INSPECTION AND DISPLAY OF GOLD SPECIMENS

Public Resources Code, Sec. 2250:

> "It is unlawful for any person to engage in the business of milling, sampling, concentrating, reducing, refining, purchasing, or receiving for sale, ores, concentrates, or amalgams bearing gold or silver, gold dust, gold or silver bullion, nuggets, or specimens without first procuring the license provided for by this chapter."

Sec. 2253:

> "The application for a license to carry on such business shall be made to the State Mineralogist . . ."

Sec. 2267:

> "Every licensee under this chapter shall file monthly with the State Mineralogist a report of all purchases made under this chapter. The reports shall be made upon forms prescribed by the State Mineralogist and shall contain the information required by this chapter."

During the 100th fiscal year the ore buyers inspector spent 101 days in the field, made 306 contacts, and investigated 23 cases. No arrests were made. In 1947 there were issued 43 gold buyers licenses limiting the buyer to $1000 in purchases; in 1948 there were 47 issued. In 1947 fifty unlimited licenses were issued, and in 1948 fifty-five.

The ore buyers inspector fulfilled several requests for gold exhibits from various fairs and groups in connection with the gold-rush centennial. Cooperation was received from Mr. C. L. Best, Walnut Creek, Charles McKibbon and John Ghiorso, Sonora, and many others who turned over their most prized gold specimens to make these gold shows possible. Gold exhibits totaling a value of $335,000 were displayed on 10 different occasions to fairs and other centennial celebrations where several hundred thousand persons viewed the exhibits. In Grass Valley $140,000 of actual gold value was on display for 2 days.

MINERAL COMMODITY SURVEYS

Public Resources Code:

> "2205. The State Mineralogist shall:
>
> (a) Make, facilitate, and encourage special studies of the mineral resources and mineral industries of the State."

There is no type of work which the Division of Mines can do that is more desired by the mineral industry than a state-wide survey of individual mineral commodities. Mineral industries seeking properties to develop, investors wishing to place their money advantageously, and manufacturers looking for new mineral materials for use in their processes, all are vitally interested in securing state-wide treatises on the occurrences, distribution, grade, and economic possibilities of the different mineral commodities available in California. Bulletins of the Division on iron, manganese, copper, quicksilver, chromite, tungsten, and other commodities are in constant demand.

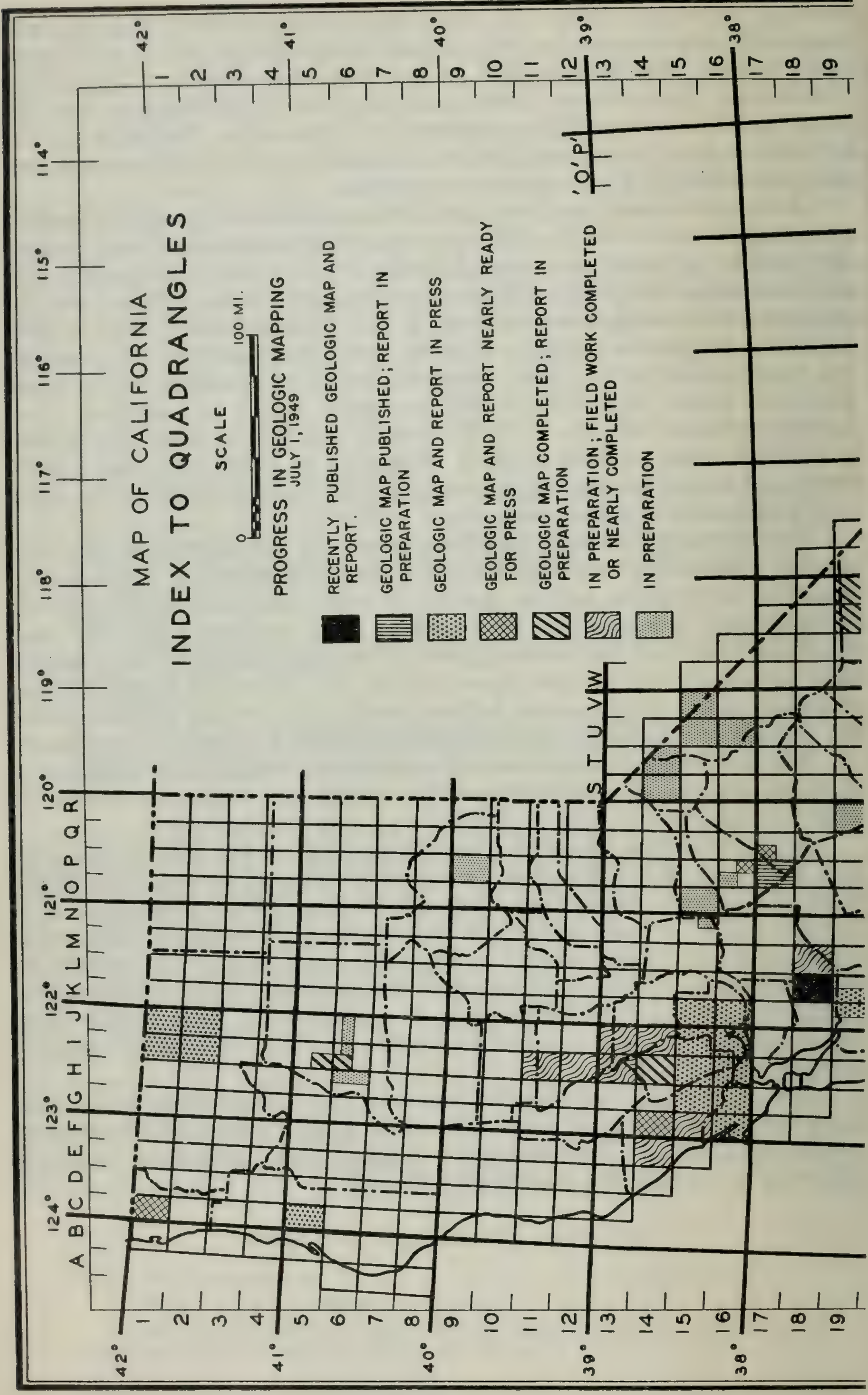
During the past fiscal year, the Division has been engaged in making commodity surveys of the following nonmetallic minerals: talc, pumice and perlite, gypsum, clay, and kyanite. These studies are well under way and when completed will be outstanding reports of their kind. In order to make these investigations, it has been necessary for the field geologists to become familiar with the detailed geology of many of the less known mountainous and desert regions of California, for in these areas are found potential natural resources which will support California's mineral markets in the future. In doing this work, cooperation is secured from various sources including in particular the federal Bureau of Mines, Geological Survey, the universities, as well as the many civic and county organizations.

It is planned that such detailed studies will continue for nonmetallic mineral commodities for which there is special demand, as for example: limestone, aggregates, salines, pyrite, fluorspar, asbestos, foundry sands, feldspar, and pyrophyllite. To complete these studies in the way they should be done will take several years of intensive work by the younger field personnel. At various times during the period of investigations, progress reports are presented before groups of interested persons, where the reports are discussed and suggestions made for their improvement.

The detailed commodity surveys include the study of geologic structure and control of mineral deposition which has a direct relationship with the natural reserves of California's mineral resources.

In order to plan ahead and to arrange to have the most-needed surveys done first, the preparation of a general mineral commodity bulletin is under way and will be published early in the 1949-50 fiscal year. This bulletin will review all known mineral resources throughout California, covering briefly what is known on the subjects of occurrence, economics, and production. To the preparation of this bulletin practically the entire technical staff has contributed and, in contributing, each member has become better acquainted with the problems which confront the mineral industry of California.

One of the greatest mineral commodities of California is the soil. Moreover, one of the great mineral markets is agriculture, which requires certain minerals to replenish over-cropped soils, and other mineral materials to improve the condition of the soil.


MAP OF CALIFORNIA
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PROGRESS IN GEOLOGIC MAPPING
JULY 1, 1949
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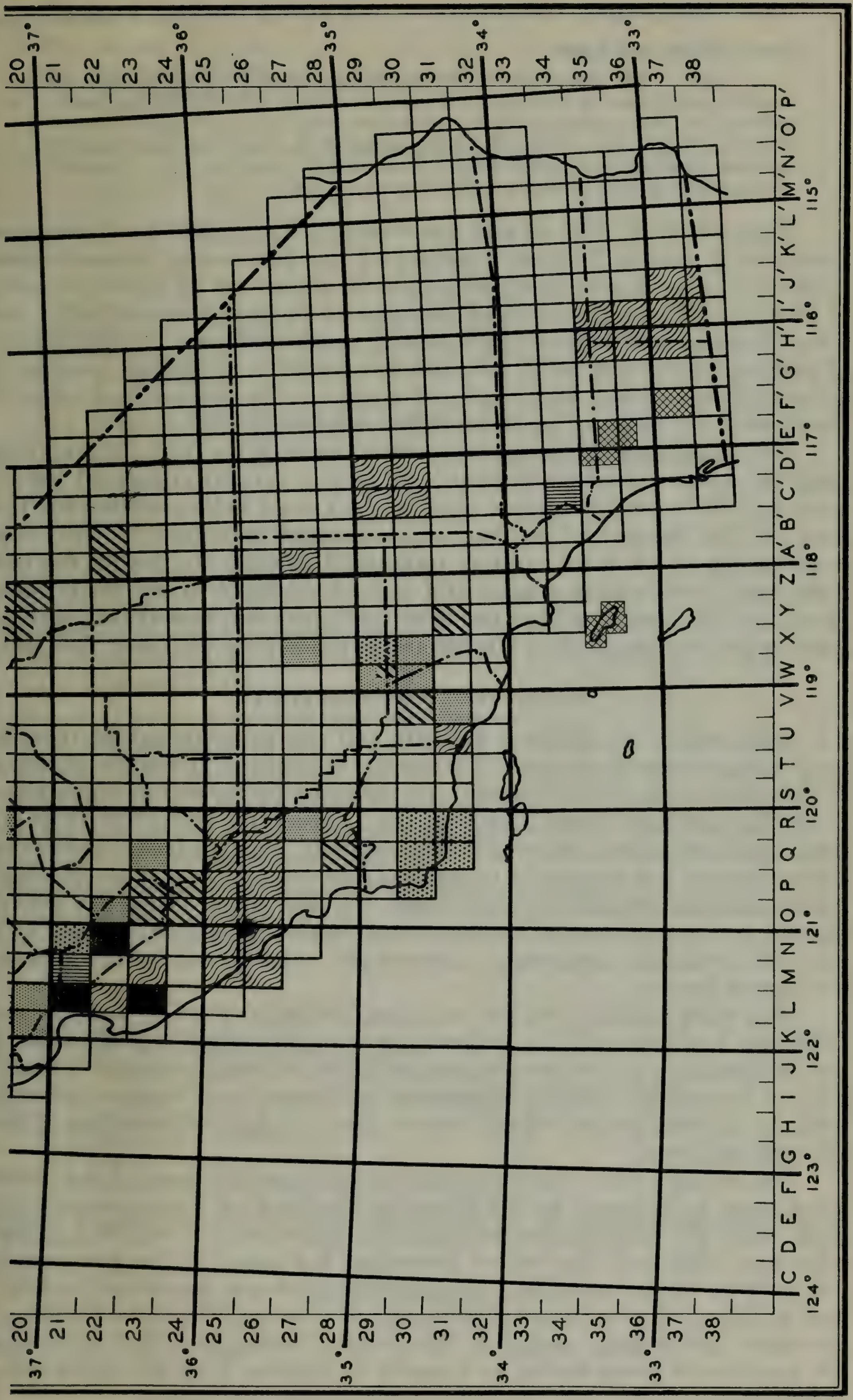
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FIGURE 3.

CONTRIBUTIONS TO EXPLORATION FOR MINERAL FUELS

Public Resources Code:

> "2200. For the purposes of this chapter 'mine' includes all mineral bearing properties of whatever kind or character, whether underground, quarry, pit, well, spring or other source from which any mineral substance is or may be obtained. 'Mineral' for the purposes of this chapter includes all mineral products both metallic and nonmetallic, solid, liquid or gaseous, and mineral waters of whatever kind or character."

Exploration by the oil and gas industry during the past year was particularly active. The contributions of the Division of Mines to this industry consisted principally of published reports on oil fields (re-issue of Bulletin 118), on the basement complex in the San Joaquin Valley, on water-flooding as a method of increasing production, and on the geology of quadrangles as well as of the state as a whole. In addition, reviews of oil and gas operations were included in the county reports, and news of discoveries was recorded in *Mineral Information Service.*

The Division of Mines plans to continue with the geologic mapping program as an aid to the industry, to issue a revised annotated list of wells and the rocks penetrated outside the known fields, to continue the study of the basement complex, to supplement Bulletin 118 with new descriptions of oil fields, and to undertake further studies on the gas fields and the bituminous sand and shale deposits. A study should also be made of the coal and peat resources in California. It will take several years to accomplish all these studies and to publish the results of the work.

BASIC GEOLOGIC MAPPING

Exploration for mineral deposits and the development of them is very largely dependent upon a thorough knowledge of the distribution of different kinds of rock formations, obtained by careful geologic mapping. The geologic maps issued by the Division of Mines are in great demand by engineers, scientists, industrialists, agriculturists, and many other persons, but especially by exploration departments of the mining, and oil and gas companies. Accordingly, the Division of Mines has undertaken a program of geologic mapping throughout California, using as a base the available topographic quadrangle units issued by the federal Geological Survey.

The work of this geologic mapping program is being done in the following manner: (a) by cooperation with geological departments of the universities; (b) by cooperation with the federal Geological Survey; (c) by cooperation with professional geologists previously associated with the universities or federal Survey; and (d) by staff members of the Division of Mines.

The status of the basic mapping program at the close of the 100th fiscal year is indicated in the following list and on the accompanying index map. The quadrangles listed are 15-minute (scale 1:62,500), unless otherwise indicated. The letter preceding the name of the quadrangle indicates the affiliation of the geologists who are doing the work: D—Division of Mines; U—university geologist; S—Federal Geological Survey; O—other professional geologist. The symbol (example, L 23) following the quadrangle name serves as a means of locating it on the index map. (plate 3).

Published, with report:

(U) Jamesburg (L 23)
(U) San Benito (N 22)
(U) San Juan Bautista (L 21)
(U) Tesla (L 18)

Geologic maps published; reports in preparation

(U) Copperopolis (P 17)
(U) Hollister (M 21)
(O) Lake Elsinore (C^1 34)

Geologic maps and reports in press

(U) Antioch (K 16)
(U) Blue Lake (C 5)
(U) Carquinez (J 16)
(O) Gaviota (R 31)
(O) Lompoc (Q 30)
(O) Los Olivos (R 30)
(U) Macdoel, 30-min. (I 1, I 2, J 1, J 2)
(U) Mare Island (I 16)
(U) Mount Vaca (J 15)
(S) Neenach (X 29)
(U) Petaluma (H 16)
(O) Point Arguello (P 30)
(O) Point Conception (Q 31)
(U) Point Reyes (G 16)
(U) Quien Sabe (N 21)
(U) Santa Rosa (H 15)
(U) San Jose-Mt. Hamilton (KL 19)
(U) Sonoma (I 15)
(U) Vacaville (K15)

Geologic maps and reports nearly ready for processing

(S) Cuyamaca Peak (F^1 37)
(S) Gasquet (C 1)
(U) Healdsburg (G 14)
(S) Mother Lode (P 16), Q 17)
(S) Pala pegmatite area (D^1 35, E^1 35, E^1 36)
(S) Santa Catalina Island (X 35, Y 35)

Geologic mapping practically completed; reports in preparation

(S) Big Pine (Y 20)
(S) Bishop (Y 19)
(S) Cerro Gordo (A^1 22)
(O) Hines Peak (30)
(U) Lebec (7½-min.) (W 29)
(S) Mt. Goddard (X 20)
(S) Mt. Humphreys (X 19)
(U) Nipomo (Q 28)
(U) Priest Valley, 30-min. (O 23, O 24, P 23, P 24)
(U) St. Helena (I 14)
(D) San Fernando (Y 31)
(S) Shasta Copper belt (I 5, 6)
(S) Ubehebe Peak (B^1 22)

Geologic maps in preparation; field work completed or nearly completed, reports to be written.

(U) Adelaida (O 26)
(D) Barstow, 30-min. (C^1 29, C^1 30, D^1 29, D^1 30)
(U) Bradley (O 25)
(U) Branch Mt. (R 28)
(U) Bryson (N 25)
(U) Capay (J 14)
(U) Cape San Martin (M 25)
(U) Carbona (M 18)
(U) Cholame, 30-min. (Q 25, Q 26, R 25, R 26)

(U) Fort Ross area (F 14)
(O) Imperial Valley quadrangles
  Agua Dulce (H^1 35)
  Barrel Spring (H^1 36)
  Brawley (J^1 37)
  Carrizo Mt. (H^1 37)
  Coyote Wells (H^1 38)
  Durmid (I^1 35)
  Heber (J^1 38)
  Kane Spring (I^1 36)
  Plaster City (1^1 37)
(U) Lodoga (I 11)
(U) Morgan Valley (Reiff) (I 13)
(U) Paso Robles (P 26)
(U) Piedras Blancas (M 26)
(U) Rumsey (J 13)
(U) Salinas (L 22)
(O) Saltdale (A^1 27)
(U) San Miguel (P 25)
(U) San Simeon (N 26)
(U) Sebastopol (G 15)
(U) Soledad (M 23)
(U) Ventura (U 31)
(U) Wilbur Springs (I 12)

Geologic mapping under way; reports to be prepared

(U) Blairsden (P 9)
(O) Breckenridge Mt. (X 27)
(U) Bridgeport, N. ½ 30-min. (U 15, V 15)
(U) Indian Gulch (R 19)
(U) Joaquin Rocks (Q 23)
(U) La Panza (R 27)
(U) Los Gatos (New Almaden) (K 20)
(U) Markleeville, S. ½ 30-min. (S 14, T 14)
(D) Matterhorn Peak (U 16)
(U) Morgan Hill (L 20)
(S) Mother Lode (N 15, O 15, P 16)
(U) Panoche Valley (O 22)
(U) Santa Paula (V 31)
(S) Shasta Copper belt (H 6, I 6, J 6)
(U) Sutter Creek (O 15)
(U) Tejon (except Neenach and Lebec) (S 14, T 14)

REGIONAL STATE MAP

In 1938 the Division of Mines issued a colored regional geologic map, scale 1:500,000 (wall map size 7 feet x 7 feet). It represented a very careful compilation of all the available data of that time, but it should now be revised to include new data. During the 100th fiscal year 460 copies of this map were sold, largely to exploration departments of oil companies, and at this rate of sale the remaining stock will be exhausted in 1½ years. The Division, therefore, should plan to revise this map and re-issue it early in the 102d fiscal year (1951-52).

This same state map, but without formational colors and on reduced scale of 1:1,000,000, has been republished several times to show by a red overprint the distribution of various mineral commodities, such as oil and gas, quicksilver, chromite, manganese, tungsten, and copper. This program of issuing state-wide distribution maps of economic minerals, with marginal explanatory material, to accompany mineral commodity reports, constitutes one of the continuing programs of the Division of Mines. The maps are in constant demand, and are especially valuable in planning programs of exploration and field examinations.

POPULAR GEOLOGIC AND MINING GUIDEBOOKS

It is difficult for the general public always to appreciate the nature or value of technical studies on mining operations or geology because the reports are clouded in technical phrases of the profession and do not include items of ordinary human interest. In order to meet this criticism, the Division of Mines prepared and issued during this last fiscal year Bulletin 141, *Geologic Guidebook Along Highway 49—Sierran Gold Belt, The Mother Lode Country.* The reception of this volume far exceeded expectations. The first issue of 7500 sold out in less than 2 months; the second issue of 10,000 is going rapidly. Ordinarily the publications of the Division are printed in issues of 2000.

Following the lesson learned from Bulletin 141 and from the scores of letters of appreciation received from enthusiastic readers, the Division of Mines plans to issue a geologic guidebook of the counties of the San Francisco Bay area to serve as a background for an industrial study which is now being made by the San Francisco Chamber of Commerce. This new guidebook will contain contributions from more than 30 scientific authorities and will be well illustrated with pictures and maps. It should answer queries on scores of scientific, historical, and mining subjects.

Another semi-technical book will also be issued by the Division of Mines on the physical features and development of the landscape of California as a whole. It is expected that this volume will be found especially useful by educational institutions of the state that give courses of study in physical geography and the geological sciences.

If these more popular types of publications are found to serve a good purpose in directing the attention of the public toward the importance of California's mineral resources and their relationship to a growing industrial civilization, it may be found advisable to continue a series of such volumes covering other areas, such as the Los Angeles district, the coast highway, Highway 395, and the frontier area of the Klamath Mountains.

REPORT OF U. S. GEOLOGICAL SURVEY ON COOPERATION PROGRAM

(Annual report, 100th Fiscal Year, July 1948-June 1949)
(Submitted by United States Geological Survey)

Geological investigations of mineralized areas in California were continued by the U. S. Geological Survey under a cooperative agreement with the California State Division of Mines during Fiscal 1949, the fourth year of the cooperative program, on about the same scale as in the previous years. Expenditures for the year amounted to about $97,000, as compared with $105,000 for the previous fiscal year, and the costs were shared equally by both organizations.

The Survey personnel engaged in the program increased during the last fiscal year from 22 to 26. Part of the increase resulted from a larger number of geologists being employed either as temporary field assistants or on a part-time basis while engaged in teaching or in taking graduate work at universities. As a result, the total time actually spent by all of the geologists was equivalent to twelve men working the full year. Another part of the increase in the number of personnel was due to the addition of a draftsman and a scientific aide to the office force in order to keep pace with the increased amount of material being processed for publication. During the year this expanded office force worked the equivalent of three full-time employees.

Between the inception of the geologic investigation of a mining area and the publication of the final comprehensive report there are several stages, each of which requires a considerable period of time for completion. These stages generally include: (1) field mapping, (2) laboratory study of rocks, fossils, and ores, (3) preparation of the report, and (4) criticism and revision of the report and redrafting of the maps for final publication. As the cooperative program has been in effect only four years, only a few reports on the smaller projects have been completed and processed for publication. While the reports on the larger projects are being completed, the State Division of Mines has been publishing a number of reports on California mining areas investigated by the Survey to the cooperative agreement. During the last fiscal year, for example, only four of the nine reports transmitted for publication resulted from geologic investigations made under the cooperative agreement, and of the ten additional reports processed and expected to be transmitted during Fiscal 1950, nearly half resulted from independent earlier work by the Survey. By the end of Fiscal 1951, however, the Survey backlog of reports on pre-cooperative program investigations will be virtually exhausted, and the reports from the cooperative studies will constitute the bulk of the material submitted to the State Division of Mines for publication. The present work schedule anticipates that at least one major report on each principal project will be available by that time.

Seven major economic projects were in progress during Fiscal 1949, and a brief summary of the status of each follows the introductory part of this report. Most of these projects are in the field mapping stage, but a few have reached the stage of report preparation. One major project—the San Diego pegmatite investigation—was completed; and one new project—the preparation of reports on California chromite deposits based on war-time studies by the Survey—was added to the program. At the end of the fiscal year the basic mapping for all the major projects was nearly completed, and during the coming year the field work and laboratory studies should be completed.

The only minor project continued during the fiscal year was the study of California limestone deposits. Four representative deposits were selected for study, and reports on these have been prepared.

In Fiscal 1950, in addition to the projects carried forward from the preceding year, it is expected that an investigation of California deposits of salines, and possibly clays, will be started. Present plans call for work to begin on the saline deposits at Owens Lake, in Saline Valley, and near the Avawatz Mountains, and on the clay deposits near Ione.

Active Projects, Fiscal 1949

Shasta copper.—Field work was concentrated in the northern part of the western copper belt extending from the Iron Mountain mine northeastward to the Sutro mine. Four 7½-minute quadrangles are being investigated as the initial part of the study of the entire belt; of these four, two were mapped in Fiscal 1948, and a third was completed in Fiscal 1949. A substantial part of the year was occupied by the preparation of reports. A detailed report on the Iron Mountain mine has been written and is being reviewed prior to transmittal to the Division of Mines for publication. In addition, a lengthy progress report containing a summary of the geology and stratigraphy, and their relation to the copper deposits was prepared; this material will form the basis of the final comprehensive report.

Mother Lode Gold Belt.—On the Mother Lode project the mapping of the 7½-minute San Andreas No. 4 and the Sonora quadrangles was completed. Most of the year was devoted to laboratory work and the preparation of a report on these two quadrangles. At the end of the year this report was 90 percent complete, and it is anticipated that it will be transmitted for publication during Fiscal 1950.

New Almaden Quicksilver District.—The mapping of the New Almaden quicksilver district occupying most of the northern half of the Los Gatos 15-minute quadrangle, was completed in Fiscal 1948. During Fiscal 1949 a comprehensive report on the geology and ore deposits of the district was submitted for criticism and returned to the author for revision. It will be transmitted for publication in Fiscal 1950.

Bishop Tungsten District.—The tungsten deposits being investigated near Bishop are in four 15-minute quadrangles, tentatively named the Bishop, Big Pine, Mt. Humphreys, and Mt. Goddard quadrangles. By the end of Fiscal 1948 mapping of the two northern quadrangles and the study of most of the tungsten mines was completed. During Fiscal 1949 half the Big Pine quadrangle and the northern third of the Mt. Goddard quadrangle were mapped on aerial photographs, and it is expected that the remainder will be completed in Fiscal 1950. New topographic sheets to be used in plotting the geology from the aerial photographs have not been completed, but at least two of the sheets should be supplied early in Fiscal 1950. A report on the geology and tungsten deposits of the Tungsten Hills area was transmitted to the State Division of Mines for publication.

Cerro Gordo-Ubehebe Lead-Zinc District.—Detailed mapping on the Cerro Gordo and Ubehebe 15-minute quadrangles was continued at such a rate that it is expected the mapping will be completed during Fiscal 1950. In addition, several of the smaller mining districts in the quadrangles were studied. Reports on two of these—the Lippincott lead and the Sally Ann copper mining areas—were prepared for open file release. A third report, on the geology of the Quartz Spring area, which adjoins the Ubehebe quadrangle, is in progress and will be ready for publication in Fiscal 1950. It is expected that comprehensive reports on the geology and mines of the two quadrangles will be transmitted for publication during Fiscal 1951.

California Limestones.—The investigation of representative limestone deposits in California was continued. Four deposits in different geologic provinces were selected for study, and these were mapped to determine their size and sampled to determine their suitability for commercial use. The deposits already studied are the Gazelle deposit in the Klamath Mts., the Sonora deposit in the Sierra Nevada, the Calera limestone in the Coast Ranges south of San Francisco, and the Sierra Blanca limestone in the Transverse Ranges north of Santa Barbara. Reports on all of these have been prepared. Two have been transmitted to the Division of Mines for publication, and the other two will be transmitted in Fiscal 1950.

California Chromite.—The field mapping of the chromite deposits of California was carried on by the Survey as a part of its war-time investigations of strategic minerals. At the end of the war the Survey began to prepare comprehensive reports on these deposits in California for publication by the Division of Mines. Individual reports are prepared for single counties or groups of counties, and these are being issued as chapters in Bulletin 134 as they become available. In order to hasten completion of the series the work became part of the cooperative program in Fiscal 1949. During this year a manuscript on the chromite deposits of the northern Sierra counties was brought nearly to completion, and it is expected that this report, as well as the final one on the deposits of the southern Coast Ranges, will be completed in Fiscal 1950.

San Francisco Office.—The San Francisco office is maintained as headquarters for the cooperative work, and the full-time staff of clerk-stenographer, draftsman, and scientific aide provide necessary services to the projects. The principal services include handling correspondence and supplies, collecting geologic and mining data, and preparing texts and illustrations of manuscripts. During Fiscal 1949 twenty-five reports containing a total of 2,686 manuscript pages of text and 277 maps were processed through this office. Nine of these reports were transmitted to the Division of Mines for publication. Sixteen of the reports were the direct result of the cooperative program, and most of the time spent in typing, drafting, and checking was on them. All of the reports, however, were on some phase of geology in California and all involved some work by the San Francisco office.

CONCLUSIONS

The functions of the Division of Mines were clearly defined many years ago by the Public Resources Code. To carry out these functions and to keep abreast of the State's industrial growth, the Division requires a well organized and well trained staff of employees adequately equipped. To augment their efforts, available sources of information and actual means of assistance are marshaled into the program of procedure by cooperation between the Division and other authoritative institutions who are also engaged in similar studies. The Division serves as a clearing house for information and maintains an active body of field investigators. It serves as a medium for publishing and distributing authoritative information.

The program of work assigned to the Division of Mines is on a broad, state-wide basis, the results of which are available to all. The larger and more appreciative the audience, the broader the scope of service and the lower the cost of publications per capita. Encouragement to industry is manifested by its use of this information. Any effort that is successful in enlightening the user of minerals as to the availability of them, the producer of minerals as to their utilization, the explorer as to the occurrence and potential supply of minerals, or the operator as to successful techniques of other operators, will fulfill the most important functions of the Division and will surely result in greater prosperity for the State.

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MINES AND MINERAL DEPOSITS

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Collate 14 maps

California Chromite.—The field mapping of the chromite deposits of California was carried on by the Survey as a part of its war-time investigations of strategic minerals. At the end of the war the Survey began to prepare comprehensive reports on these deposits in California for publication by the Division of Mines. Individual reports are prepared for single counties or groups of counties, and these are being issued as chapters in Bulletin 134 as they become available. In order to hasten completion of the series the work became part of the cooperative program in Fiscal 1949. During this year a manuscript on the chromite deposits of the northern Sierra counties was brought nearly to completion, and it is expected that this report, as well as the final one on the deposits of the southern Coast Ranges, will be completed in Fiscal 1950.

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JOURNAL
VOL. 46, NO 1, PL. 22

MINES AND
MINERAL DEPOSITS
OF
SONOMA COUNTY, CALIFORNIA
BY
DIVISION OF MINES

1949

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SONOMA CO
CLOVERDALE
WESTERN MAYACMAS DISTRICT
MIDDLETOWN
CALISTOGA
Lake County
Napa County
GREAT EASTERN MINE
ARMY AIR BASE
NAVY AIR BASE
SANTA ROSA
ST HELENA
PETALUMA
HEIN BROS BASALT ROCK CO
TRICO OIL & GAS CO
NAPA
SAN PABLO BAY
Napa County
Solano County

MINERAL SYMBOLS

CLAY	◇C
CHROMITE	▬
COAL	Ⓒ
COPPER	●
DIATOMITE	◇D
GRAPHITE	Ⓖ
LIMESTONE	◇L
MAGNESITE	Ⓜ
MANGANESE	◐
PERLITE	◇P
QUICKSILVER	◑
SAND and GRAVEL	◇S
CRUSHED and BROKEN STONE	⊕
UNSPECIFIED STONE	U
FLAGSTONE	F
OIL WELL	◉
GAS WELL	☼

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

DIVISION OF MINES
OLAF P JENKINS, *Chief*

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF FORESTRY

SONOMA COUNTY
1945

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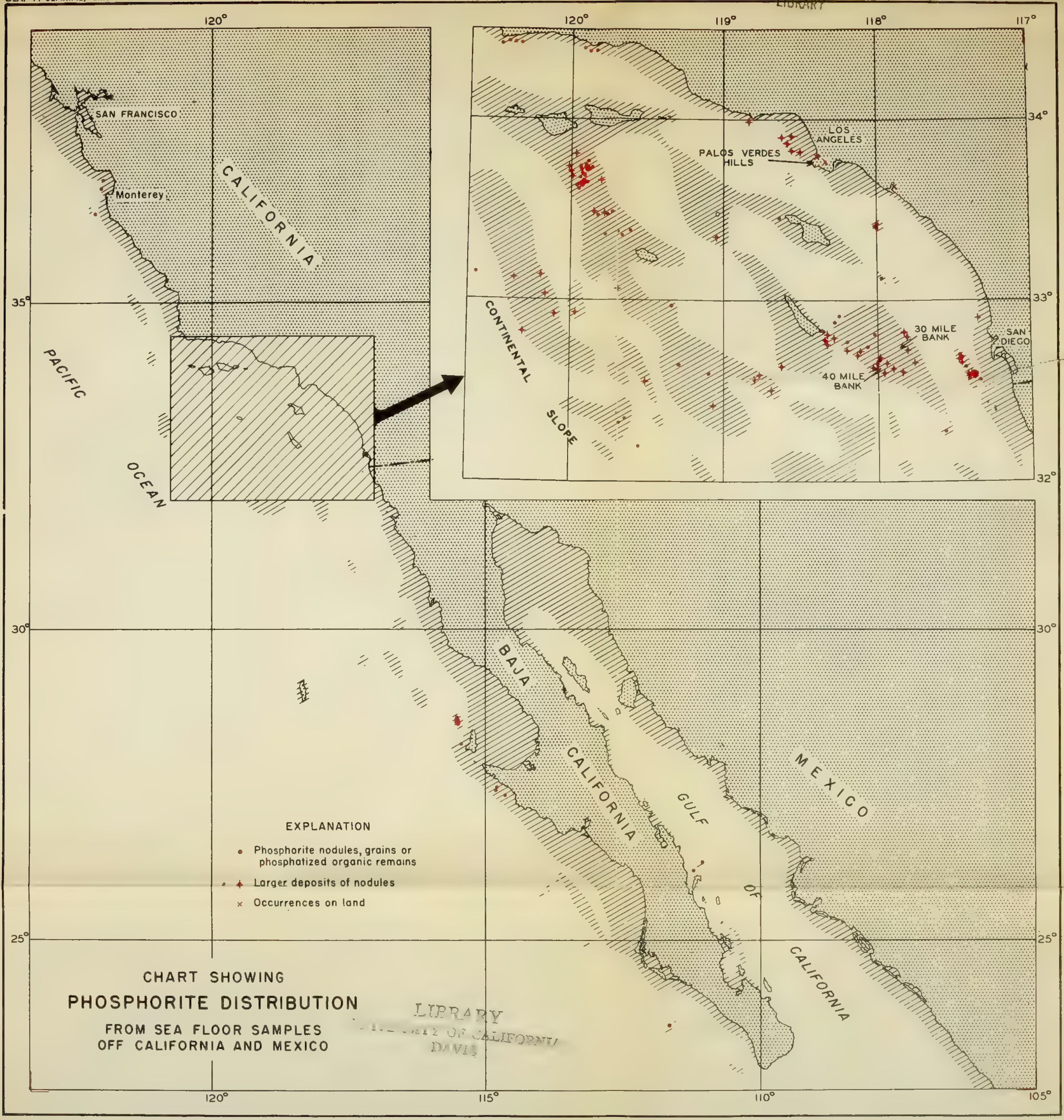
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SAN FRANCISCO
Monterey
CALIFORNIA
PACIFIC
OCEAN
LOS ANGELES
PALOS VERDES HILLS
CONTINENTAL SLOPE
30 MILE BANK
40 MILE BANK
SAN DIEGO
BAJA
CALIFORNIA
GULF
OF
CALIFORNIA
MEXICO
EXPLANATION
● Phosphorite nodules, grains or phosphatized organic remains
✦ Larger deposits of nodules
× Occurrences on land

CHART SHOWING
PHOSPHORITE DISTRIBUTION
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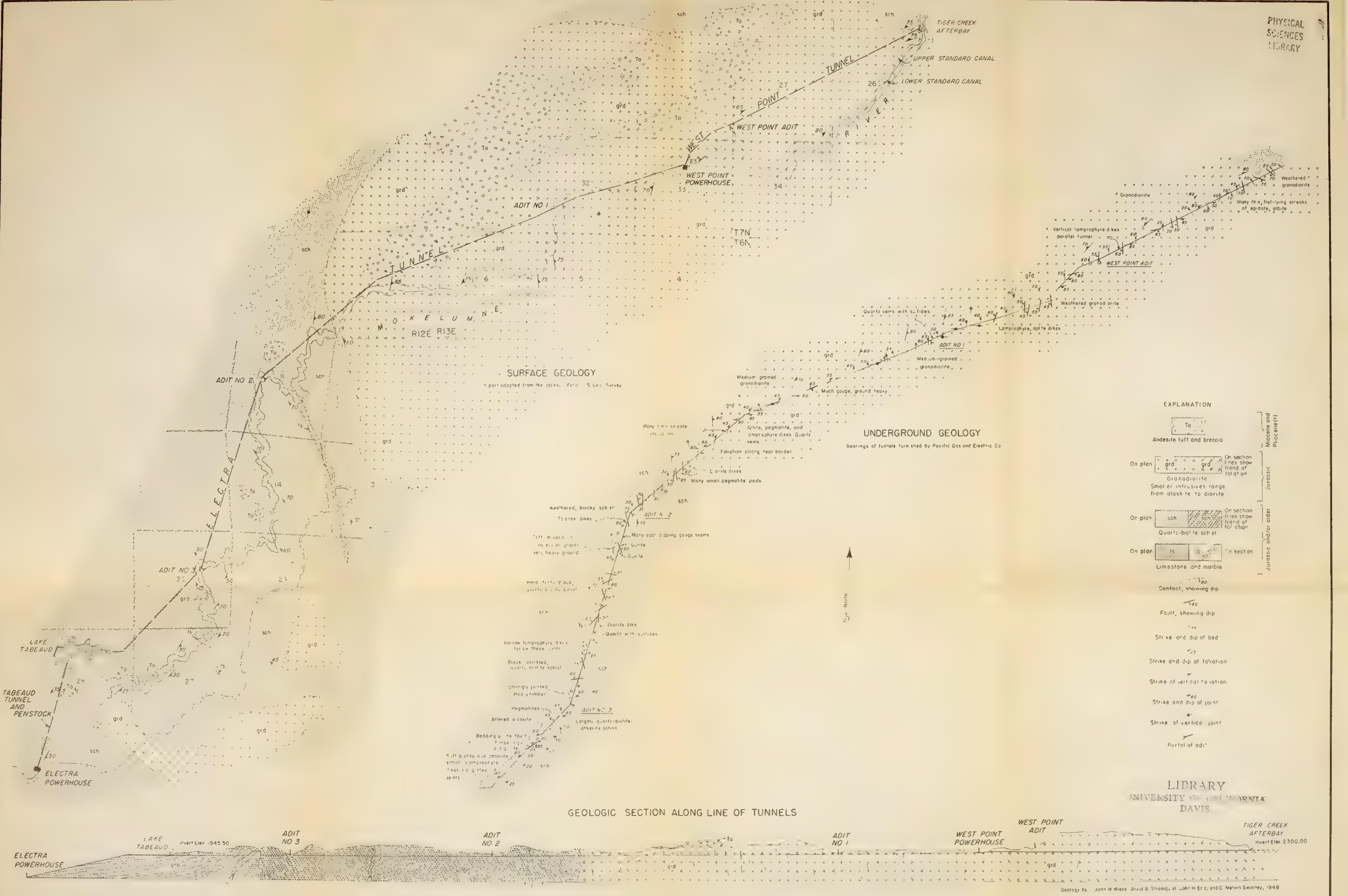
SURFACE GEOLOGY
In part adapted from the Jackson Folio, U. S. Geol. Survey
TIGER CREEK AFTERBAY
UPPER STANDARD CANAL
LOWER STANDARD CANAL
WEST POINT TUNNEL
WEST POINT ADIT
WEST POINT POWERHOUSE
RIVER
T7N
T6N
ADIT NO 1
ELECTRA TUNNEL
MOKELUMNE
R12E R13E
ADIT NO 2
ADIT NO 3
LAKE TABEAUD
TABEAUD TUNNEL AND PENSTOCK
ELECTRA POWERHOUSE
sch
grd
To
UNDERGROUND GEOLOGY
Bearings of tunnels furnished by Pacific Gas and Electric Co
Weathered granodiorite
Granodiorite
Many thin, flat-lying streaks of epidote, albite
Vertical lamprophyre dikes parallel tunnel
WEST POINT ADIT
Weathered granodiorite
Quartz veins with sulfides
Lamprophyre, aplite dikes
ADIT NO 1
Medium-grained granodiorite
Medium grained granodiorite
Much gouge, ground heavy
Many lime silicate inclusions
Aplite, pegmatite, and lamprophyre dikes Quartz veins
Foliation strong near border
Diorite dikes
Many small pegmatite pods
Weathered, blocky schist
Tonalite dikes
ADIT NO 2
Many east dipping gouge seams
Gunite
Hard, fissile, black, quartz-biotite schist
Diorite dike
Quartz with sulfides
Narrow lamprophyre dikes follow these joints
Black, crinkled, quartz-biotite schist
Strongly jointed, Heavy timber
Pegmatites
Altered alaskite
ADIT NO 3
Largely quartz-biotite-ankerite schist
Bedding plane fault
Timbering
Soft biotite and chlorite schist. Lamprophyre dikes along steep joints
True North
EXPLANATION
To
Andesite tuff and breccia
Miocene and Pliocene(?)
On plan
grd
On section lines show trend of foliation
Granodiorite
Smaller intrusives range from alaskite to diorite
Jurassic
On plan
sch
On section lines show trend of foliation
Quartz-biotite schist
On plan
ls
On section
Limestone and marble
Jurassic and/or older
Contact, showing dip
Fault, showing dip
Strike and dip of bed
Strike and dip of foliation
Strike of vertical foliation
Strike and dip of joint
Strike of vertical joint
Portal of adit
GEOLOGIC SECTION ALONG LINE OF TUNNELS
ELECTRA POWERHOUSE
LAKE TABEAUD
Invert Elev 945.50
ADIT NO 3
ADIT NO 2
ADIT NO 1
WEST POINT POWERHOUSE
WEST POINT ADIT
TIGER CREEK AFTERBAY
Invert Elev 2300.00

Geology by John H Wiese, Arvid A. Stromquist, John H Eric, and C. Melvin Swinney, 1948

GEOLOGIC MAPS AND SECTION OF THE ELECTRA AND WEST POINT TUNNELS, AMADOR COUNTY, CALIFORNIA

1000 0 1000 2000 3000 4000 5000 FEET
0 1 2 MILES

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JOURNAL
VOLUME 46 PLATE 7

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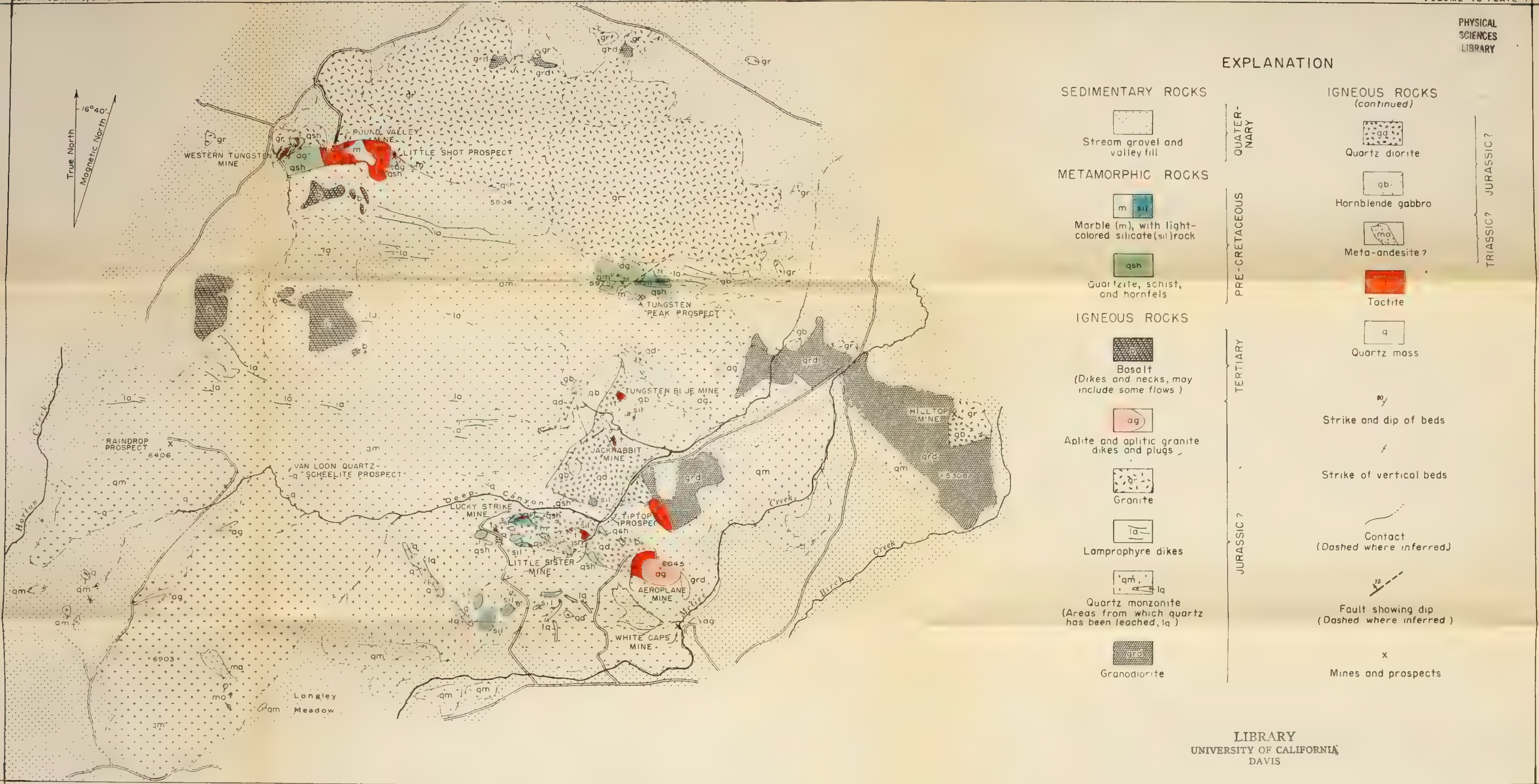
True North
Magnetic North
16°40'
POUND VALLEY MINE
WESTERN TUNGSTEN MINE
LITTLE SHOT PROSPECT
TUNGSTEN PEAK PROSPECT
TUNGSTEN BLUE MINE
JACKRABBIT MINE
HILLTOP MINE
RAINDROP PROSPECT
VAN LOON QUARTZ-SCHEELITE PROSPECT
LUCKY STRIKE MINE
TIPTOP PROSPECT
LITTLE SISTER MINE
AEROPLANE MINE
WHITE CAPS MINE
Deep Canyon
Horton Creek
Birch Creek
McGee Creek
Longley Meadow
5604
5973
6406
6903
6045
5308
EXPLANATION
SEDIMENTARY ROCKS
Stream gravel and valley fill
QUATERNARY
METAMORPHIC ROCKS
m sil
Marble (m), with light-colored silicate (sil) rock
qsh
Quartzite, schist, and hornfels
PRE-CRETACEOUS
IGNEOUS ROCKS
b
Basalt (Dikes and necks, may include some flows)
TERTIARY
ag
Aplite and aplitic granite dikes and plugs
gr
Granite
la
Lamprophyre dikes
qm lq
Quartz monzonite (Areas from which quartz has been leached, lq)
grd
Granodiorite
JURASSIC ?
IGNEOUS ROCKS (continued)
qd
Quartz diorite
gb
Hornblende gabbro
ma
Meta-andesite ?
Tactite
q
Quartz mass
JURASSIC ? TRIASSIC ?
80
Strike and dip of beds
Strike of vertical beds
Contact (Dashed where inferred)
75
Fault showing dip (Dashed where inferred)
x
Mines and prospects

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Mapped on aerial mosaic prepared by
Fairchild Aerial Surveys

Geology by Paul C Bateman
and Paul Dean Proctor

GEOLOGIC MAP OF THE TUNGSTEN HILLS
INYO COUNTY, CALIFORNIA

2000 0 2000 4000 6000 FEET

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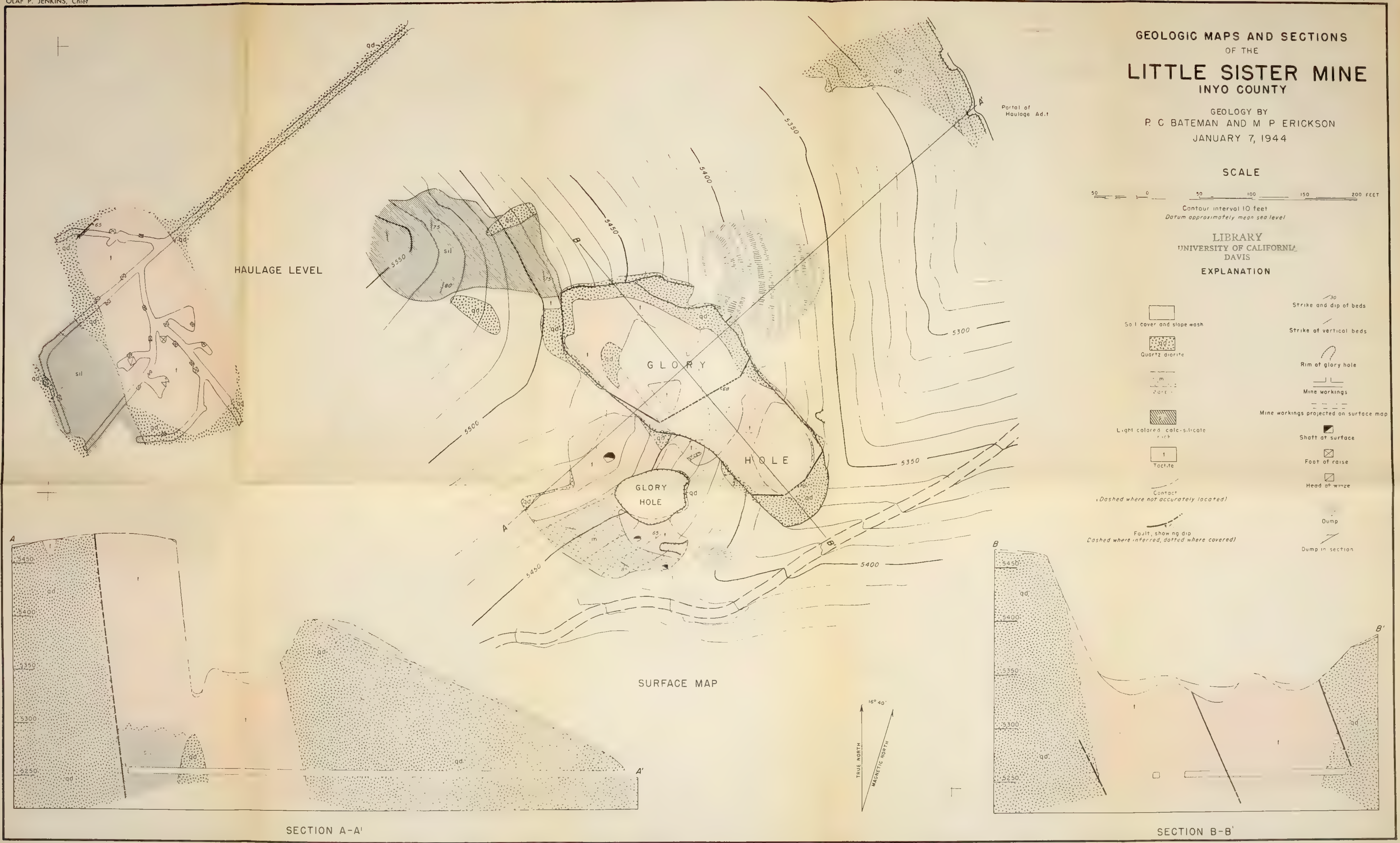

GEOLOGIC MAPS AND SECTIONS
OF THE
LITTLE SISTER MINE
INYO COUNTY

GEOLOGY BY
P. C. BATEMAN AND M. P. ERICKSON
JANUARY 7, 1944

SCALE

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50
0
50
100
150
200 FEET
Contour interval 10 feet
Datum approximately mean sea level
EXPLANATION
Soil cover and slope wash
qd
Quartz diorite
m
Marble
sil
Light colored calc-silicate rock
t
Tactite
Contact
(Dashed where not accurately located)
Fault, showing dip
(Dashed where inferred, dotted where covered)
30
Strike and dip of beds
Strike of vertical beds
Rim of glory hole
Mine workings
Mine workings projected on surface map
Shaft at surface
Foot of raise
Head of winze
Dump
Dump in section
HAULAGE LEVEL
SURFACE MAP
GLORY HOLE
GLORY HOLE
Portal of Haulage Adit
A
A'
B
B'
5300
5350
5400
5450
5500
5550
qd
t
sil
m
65
75
80
68
16° 40'
TRUE NORTH
MAGNETIC NORTH
5450
5400
5350
5300
5250
SECTION A-A'
SECTION B-B'

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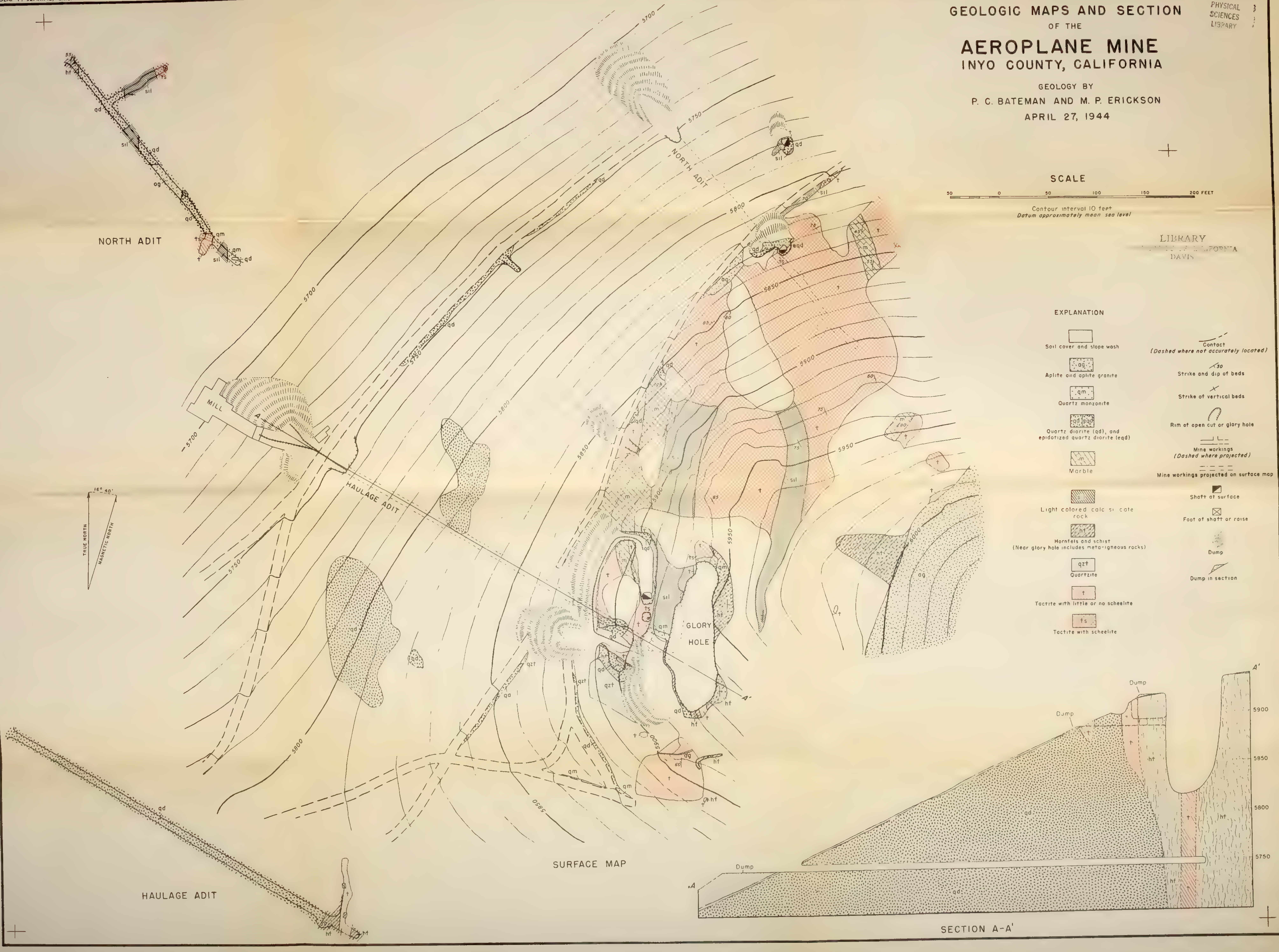
GEOLOGIC MAPS AND SECTION
OF THE
AEROPLANE MINE
INYO COUNTY, CALIFORNIA

GEOLOGY BY
P. C. BATEMAN AND M. P. ERICKSON
APRIL 27, 1944


NORTH ADIT
sil
qd
ts
ag
qm
t
SURFACE MAP
5700
5750
5800
5850
5900
5950
6000
NORTH ADIT
HAULAGE ADIT
MILL
A
A'
GLORY HOLE
m
hf
qzt
eqd
16° 40'
TRUE NORTH
MAGNETIC NORTH
HAULAGE ADIT
SECTION A-A'
Dump
5900
5850
5800
5750

SCALE

50 0 50 100 150 200 FEET

Contour interval 10 feet
Datum approximately mean sea level

EXPLANATION

▭ Soil cover and slope wash	Contact *(Dashed where not accurately located)*
ag Aplite and aplite granite	30 Strike and dip of beds
qm Quartz monzonite	Strike of vertical beds
qd eqd Quartz diorite (qd), and epidotized quartz diorite (eqd)	Rim of open cut or glory hole
m Marble	Mine workings *(Dashed where projected)*
s Light colored calc silicate rock	Mine workings projected on surface map
hf Hornfels and schist (Near glory hole includes meta-igneous rocks)	◩ Shaft at surface
qzt Quartzite	⊠ Foot of shaft or raise
t Tactite with little or no scheelite	Dump
ts Tactite with scheelite	Dump in section

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OLAF P. JENKINS, *Chief*

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DEPARTMENT OF NATURAL RESOURCES

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

VOL. 46, NO. 1, PL. 10

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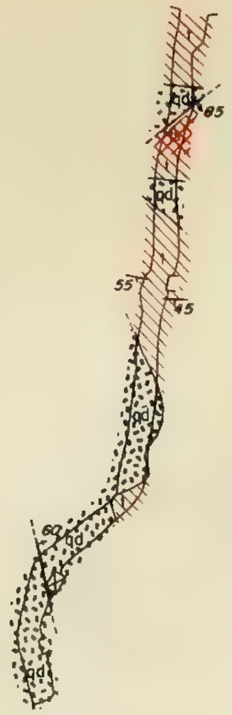
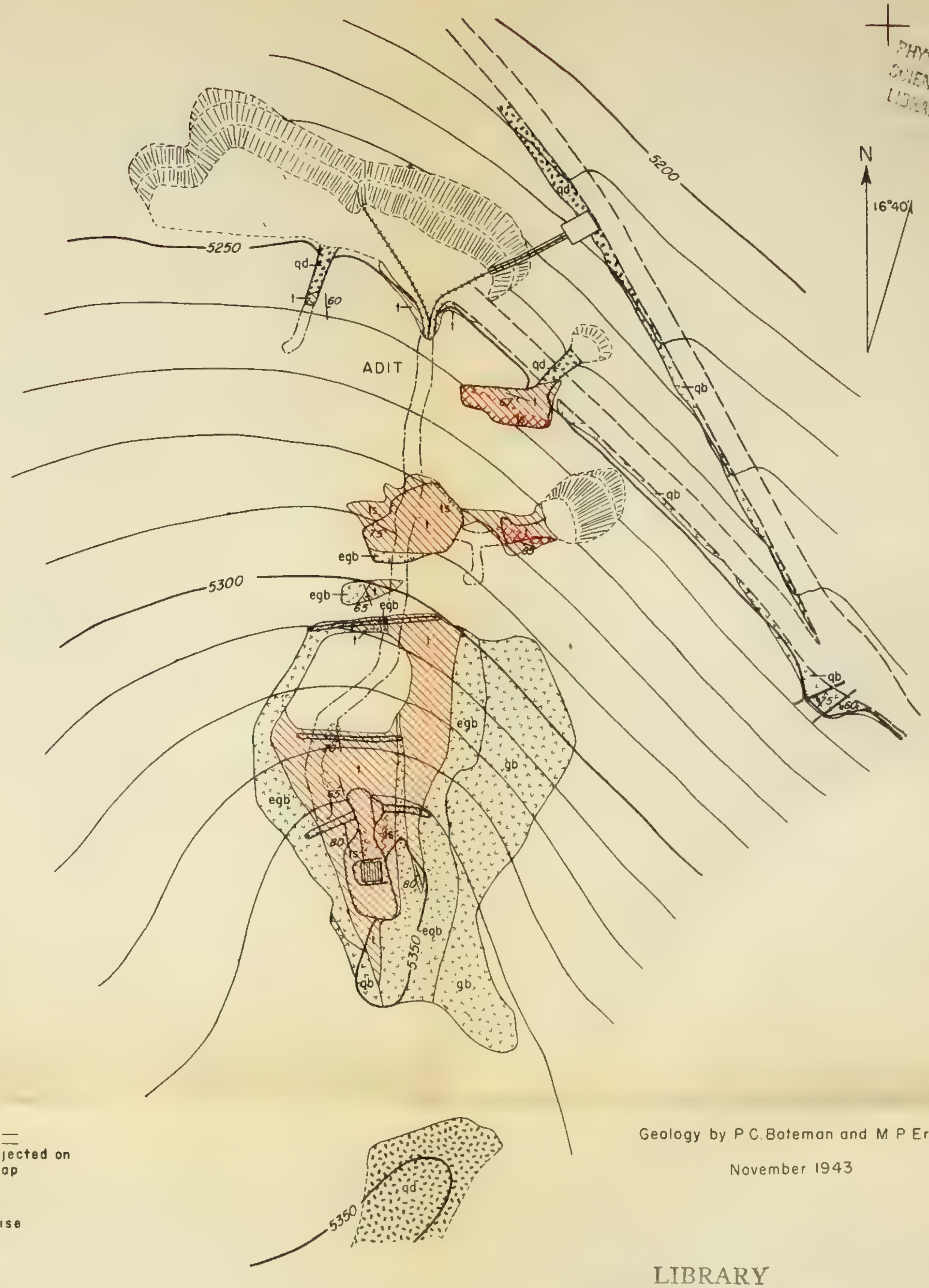


ADIT LEVEL



EXPLANATION

☐ Soil cover and slope wash

▨ gd Quartz diorite

▨ gb egb Hornblende gabbro, and epidotized gabbro

▨ t Tactite containing little or no scheelite

🟥 ts Tactite with scheelite

Contact
(Dashed where not accurately located)

Fault, showing dip
(Dashed where inferred)

Strike and dip of beds

Rim of glory hole or trench

Mine workings projected on surface map

☒ Foot of raise

Grizzly

Chute

Dump in plan

Geology by P. C. Bateman and M. P. Erickson

November 1943

SURFACE MAP

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GEOLOGIC MAPS OF THE JACK RABBIT MINE
INYO COUNTY, CALIFORNIA

50 0 50 100 150 FEET

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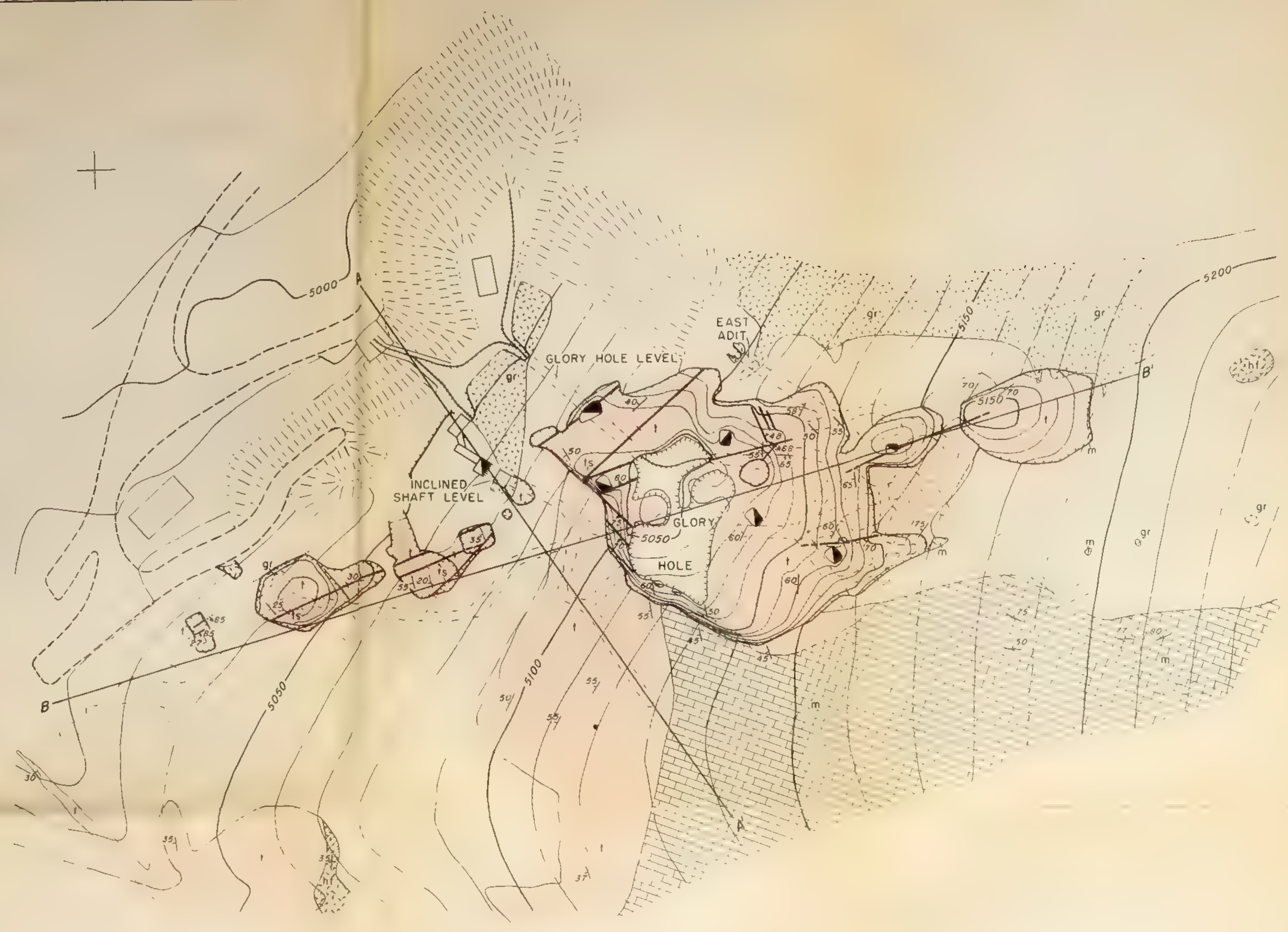
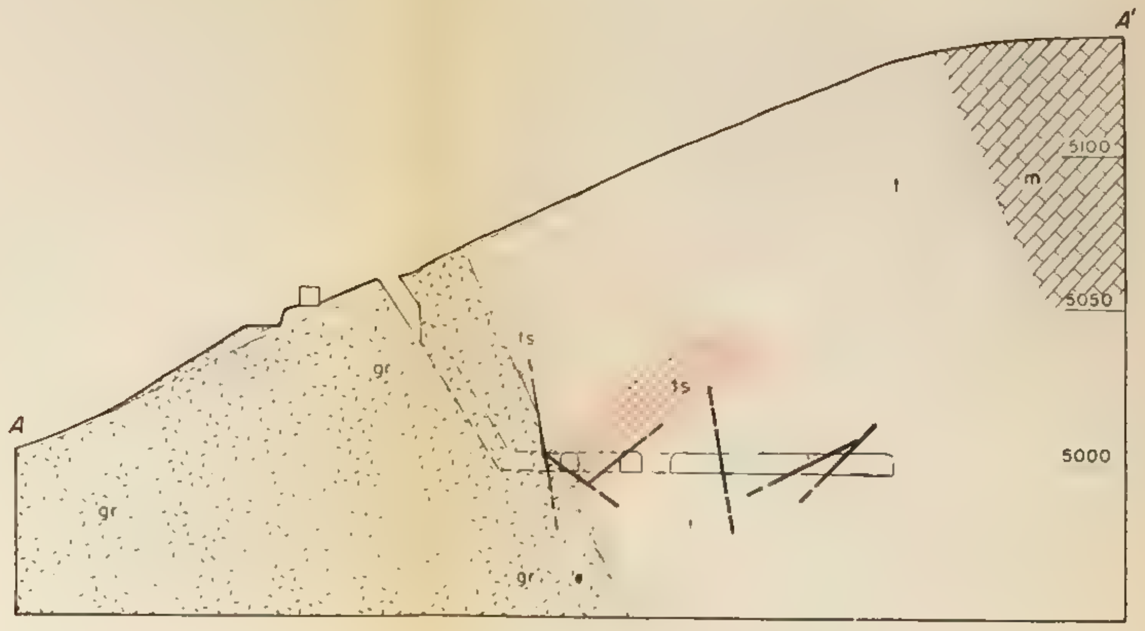
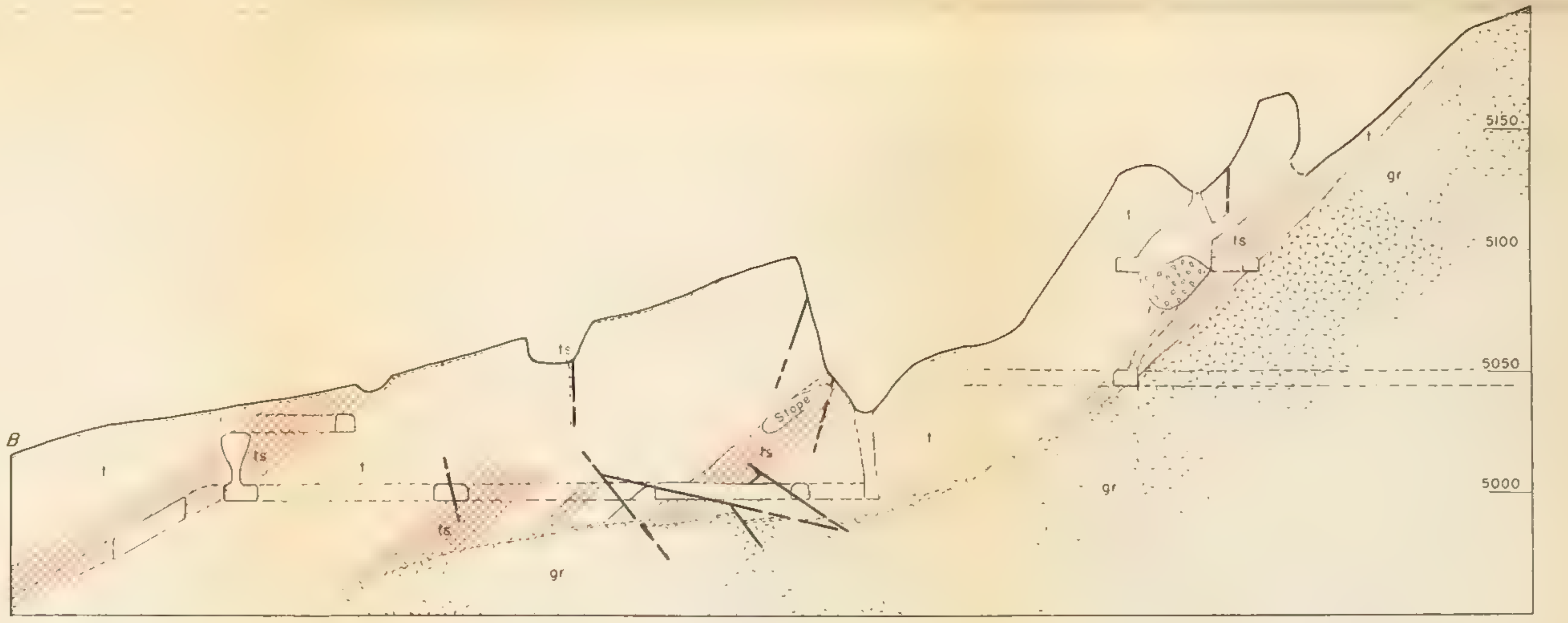

EAST ADIT
GLORY HOLE LEVEL
INCLINED SHAFT LEVEL
GLORY HOLE
5000
5050
5100
5150
5200
A
A'
B
B'
gr
t
ts
m
hf

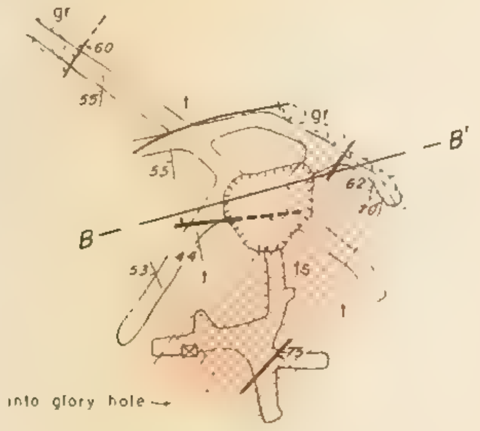
SURFACE MAP


A
A'
5100
5050
5000
gr
ts
t
m

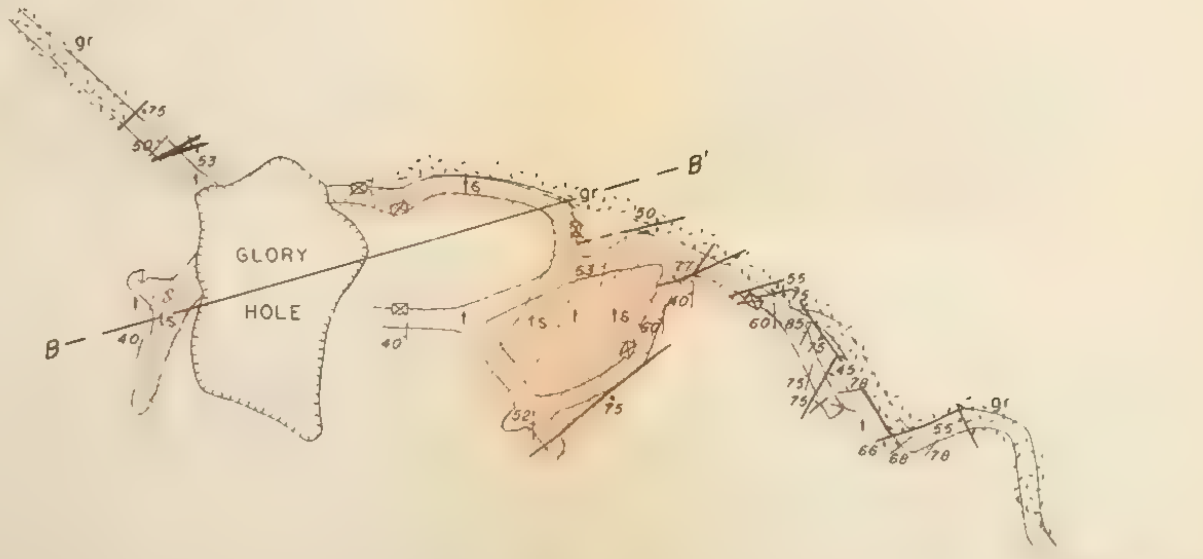
SECTION A-A'


B
B'
5150
5100
5050
5000
Stope
ts
t
gr

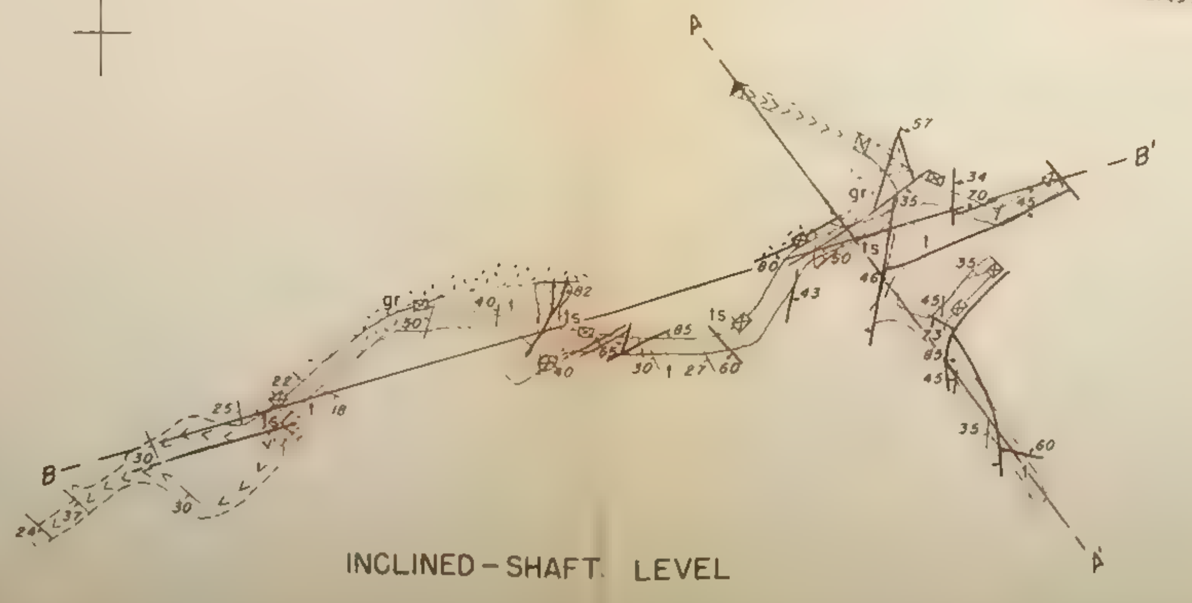
SECTION B-B'


gr
B
B'
ts
Raise into glory hole →

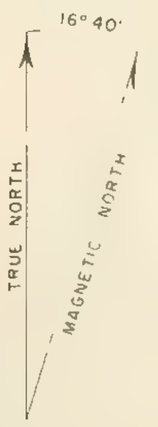
EAST ADIT


GLORY
HOLE
B
B'
gr
ts
t

GLORY HOLE LEVEL



INCLINED-SHAFT LEVEL


16° 40'
TRUE NORTH
MAGNETIC NORTH

EXPLANATION

gr	Granite
▯	Soil cover and slope wash
gr	Granite
m	Marble
hf	Hornfels and schist
t	Tactite and light-colored calc hornfels, contains little or no scheelite
ts	Tactite with scheelite
⌒	Contact (Dashed where not accurately located)
50	Fault, showing dip (Dashed where inferred, dotted where covered)
⌒	Vertical fault
55	Strike and dip of beds
⊥	Strike of vertical beds
⌒	Rim of glory hole or open cut
⌐	Mine workings
- -	Mine workings projected on sections
-	Mine workings projected on surface map
≺≺≺	Inclined workings (Chevrons point down)
◪	Shaft at surface
▭	Foot of shaft or raise
▭	Head of winze
∴	Dump
⊿	Dump in section
∴	Mine muck

GEOLOGIC MAPS AND SECTIONS
OF THE
ROUND VALLEY MINE
INYO COUNTY

GEOLOGY BY
P C BATEMAN AND M P ERICKSON
JANUARY 22, 1944

SCALE

0 50 100 150 200 FEET

Contour interval 10 feet
Datum approximately mean sea level

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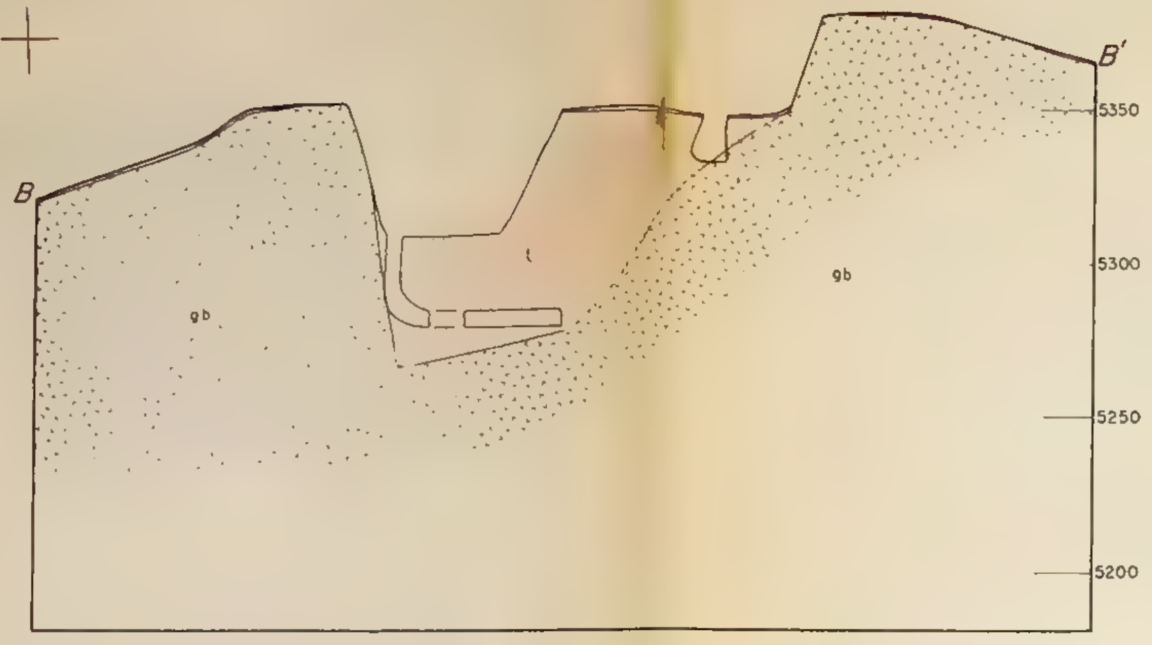
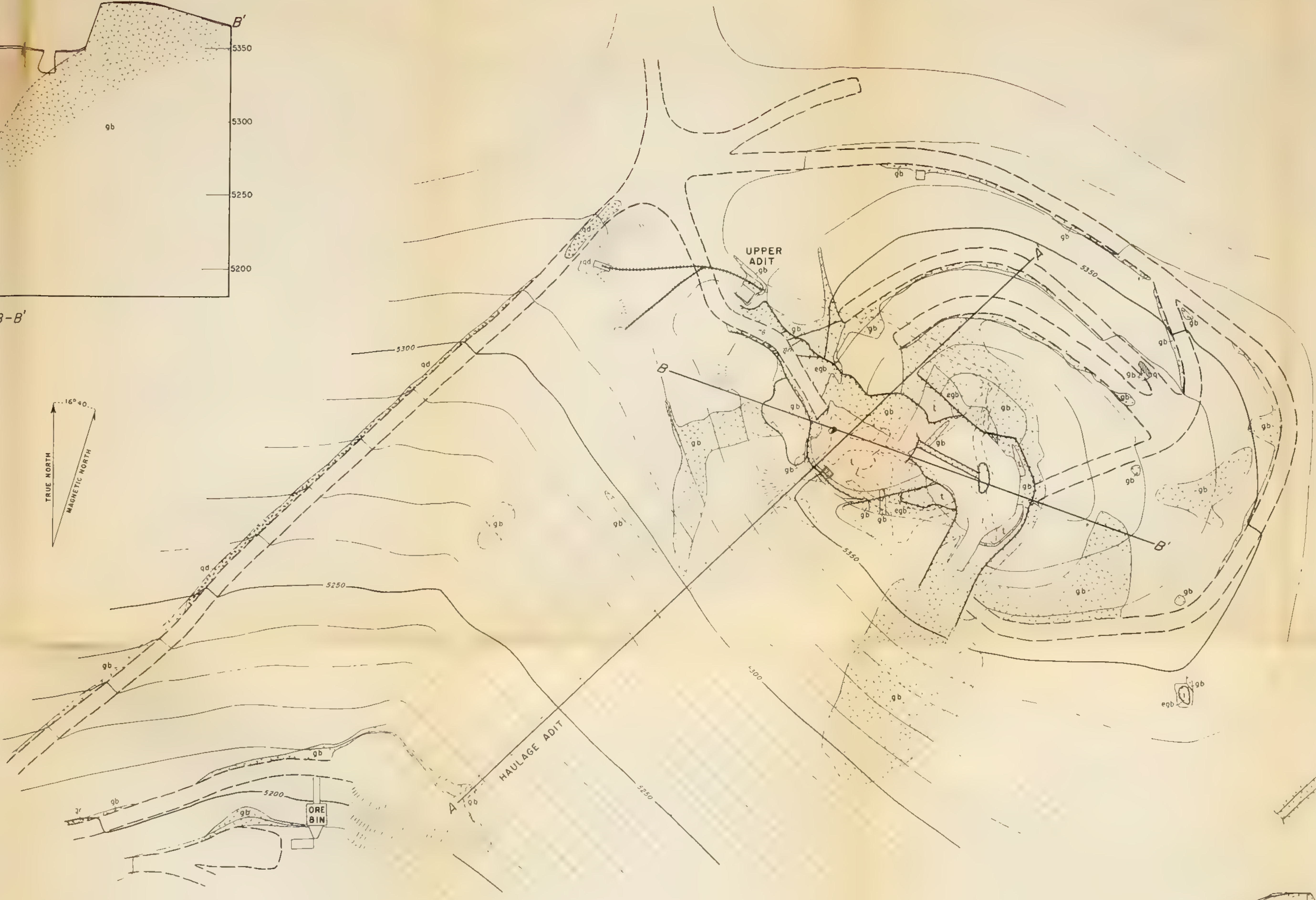

B
B'
5350
5300
5250
5200
gb
t
gb

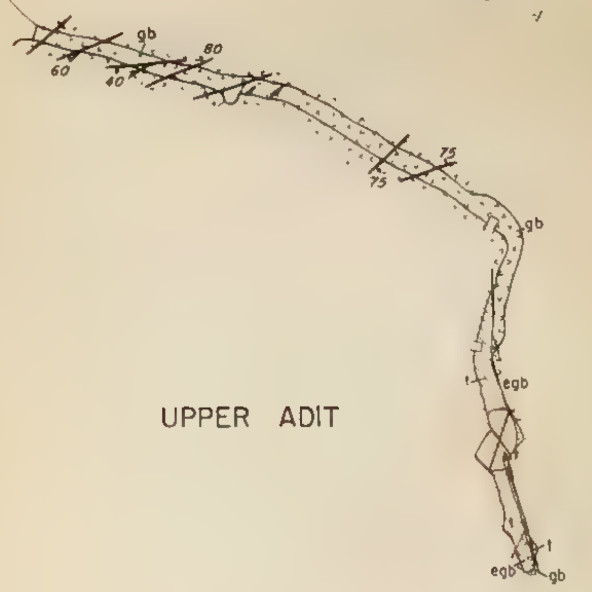
SECTION B-B'

EXPLANATION

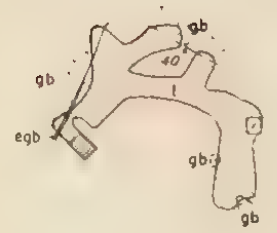
- Soil cover and slope wash
- gr — Granite
- qd — Quartz diorite
- gb | egb — Hornblende gabbro, and epidotized gabbro
- q — Quartz
- t — Tactite
- 45 — Contact, showing dip (Dashed where not accurately located)
- 70 — Fault, showing dip (Dashed where inferred, dotted when covered)
- Vertical fault
- Rim of glory hole or open cut
- Mine workings (Dashed where projected on section)
- Mine workings projected on surface map
- Head of shaft
- Foot of shaft or raise
- Chute
- Grizzly
- Dump in plan
- Dump in section


16°40'
TRUE NORTH
MAGNETIC NORTH
UPPER ADIT
HAULAGE ADIT
ORE BIN
A
A'
B
B'
5350
5300
5250
5200
gb
egb
qd
t

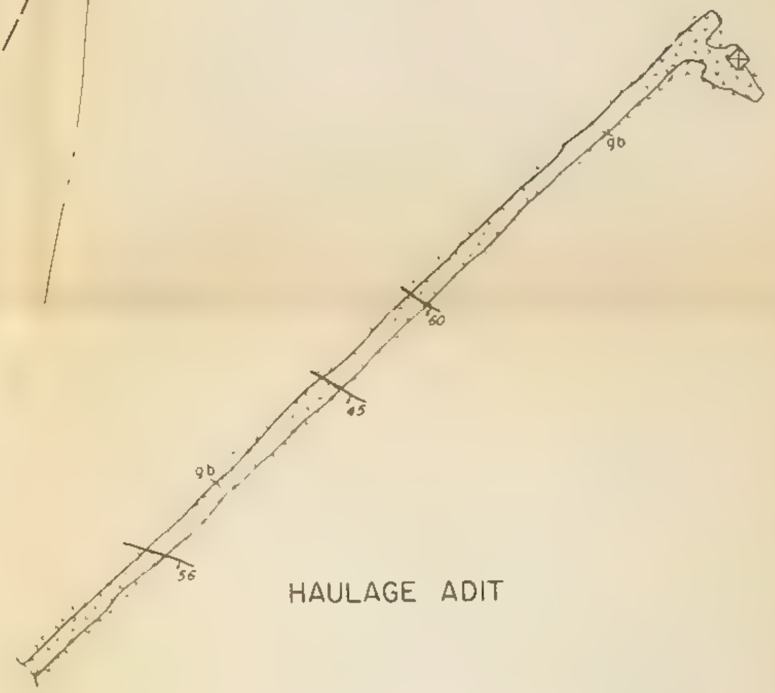
SURFACE MAP


gb
60
60
80
75
75
egb

UPPER ADIT



GRIZZLY LEVEL



HAULAGE ADIT

GEOLOGIC MAPS AND SECTIONS
OF THE
TUNGSTEN BLUE MINE
INYO COUNTY, CALIFORNIA

GEOLOGY BY
P. C. BATEMAN AND M. P. ERICKSON
DECEMBER 31, 1943   AUGUST 16, 1947

SCALE
50 0 50 100 150 200 FEET
Contour interval 10 Feet
Datum approx mean sea level

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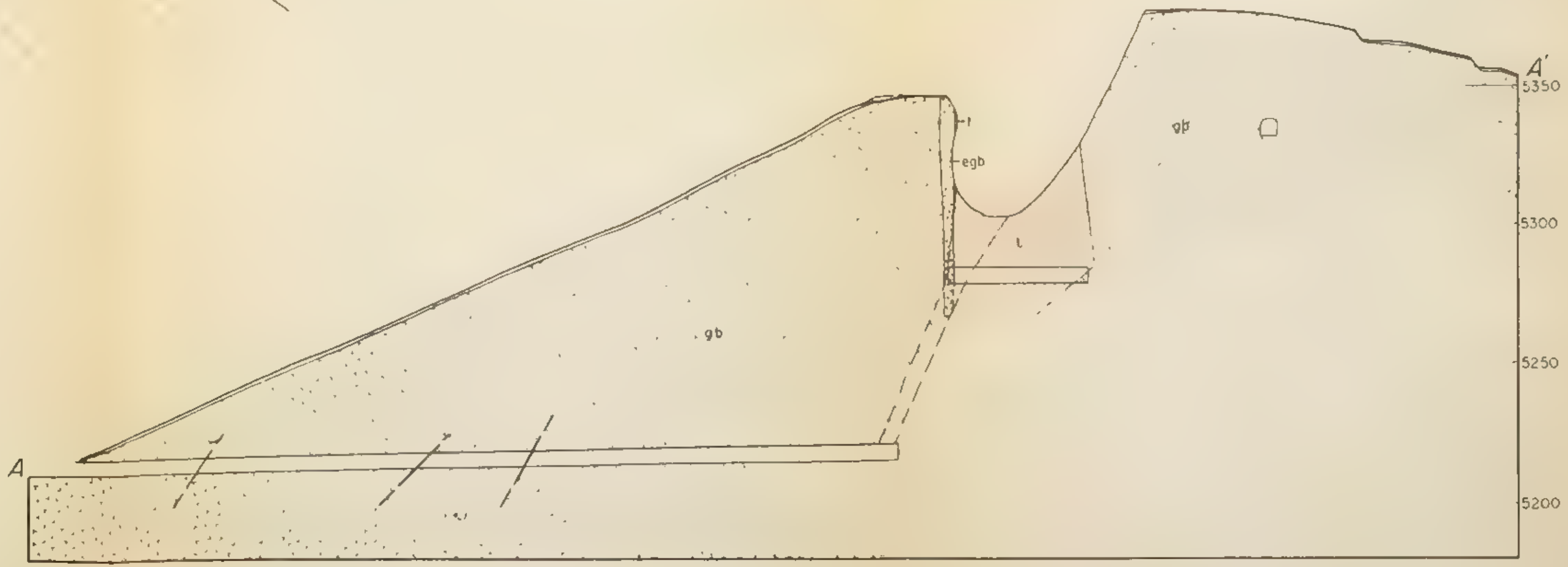
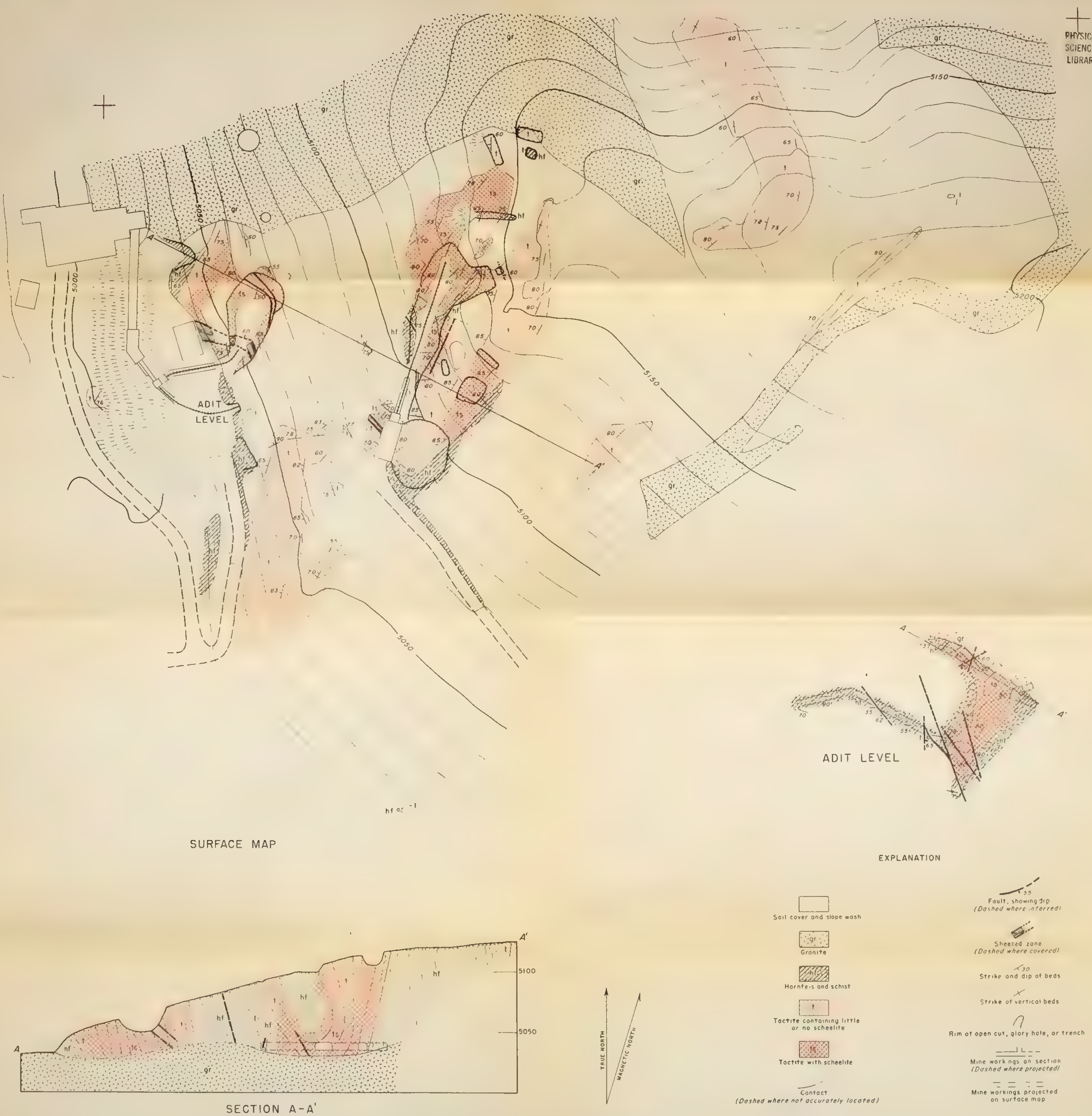

A
A'
5350
5300
5250
5200
gb
egb
t

SECTION A-A'


gr
5150
5100
5050
5000
5200
A
A'
hf
ts
t
ADIT LEVEL
SURFACE MAP
ADIT LEVEL
hf
gr
5100
5050
SECTION A-A'
TRUE NORTH
MAGNETIC NORTH
EXPLANATION
Soil cover and slope wash
Granite
Hornfels and schist
Tactite containing little or no scheelite
Tactite with scheelite
Contact (Dashed where not accurately located)
Fault, showing dip (Dashed where inferred)
Sheeted zone (Dashed where covered)
Strike and dip of beds
Strike of vertical beds
Rim of open cut, glory hole, or trench
Mine workings on section (Dashed where projected)
Mine workings projected on surface map

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GEOLOGIC MAPS AND SECTION OF THE WESTERN TUNGSTEN MINE

INYO COUNTY, CALIFORNIA

GEOLOGY BY P. C. BATEMAN AND M. P. ERICKSON

DECEMBER 11, 1943

SCALE

50 0 50 100 150 200 FEET

Contour interval 10 feet

Datum approximately mean sea level

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NORTHEAST PORTION
NEWHALL OIL FIELD
INCLUDING
PLACERITA OIL FIELD

Modified June 1949 from map of Newhall Oil
Field no. 18 A, revised June 4, 1949,
Division of Oil and Gas, R. D. Bush,
State Oil and Gas Supervisor

LEGEND

- ◒ Uncompleted, drilling
- ◇ Uncompleted, idle
- ✧ Uncompleted, abandoned
- ● Completed, producing
- ◆ Completed, idle
- ✦ Completed, abandoned

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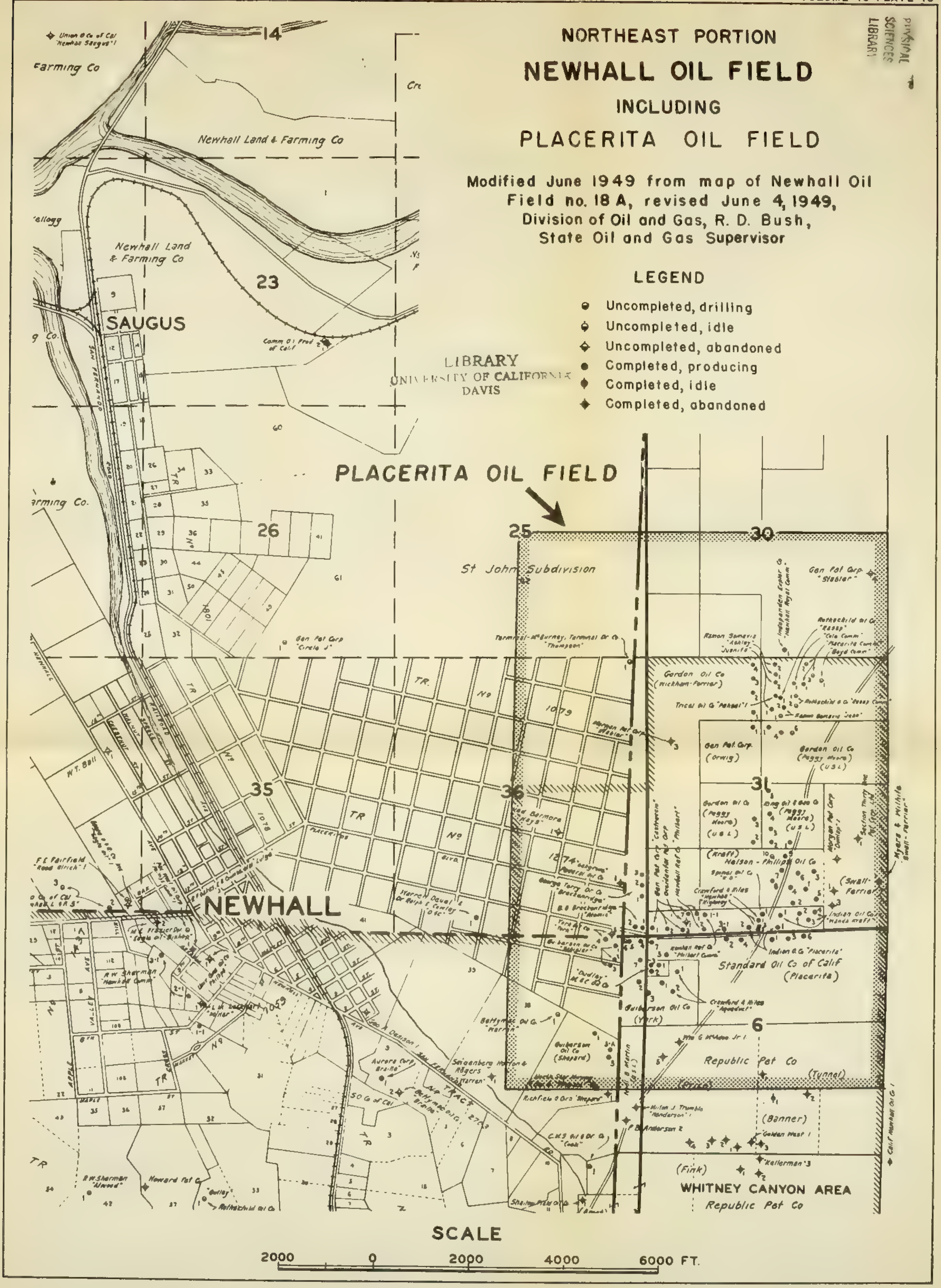
14
Union O Co of Cal "Newhall Saugus" 1
Farming Co
Newhall Land & Farming Co
Kellogg
Newhall Land & Farming Co
23
SAUGUS
Comm Oil Prod of Calif
San Fernando Road
60
PLACERITA OIL FIELD
26
35
36
25
30
31
6
St John Subdivision
Gen Pet Corp "Stabler"
Gen Pet Corp "Circle J"
Terminal-McBurney, Terminal Or Co "Thompson"
Ramon Somavia "Ashley" "Juanita"
Independent Exploration Co "Newhall Royal Comm"
Rothschild Oil Co
Gordon Oil Co (Wickham-Ferrier)
Trical Oil Co "Pahsel" 1
Gen Pet Corp (Orwig)
Gordon Oil Co (Peggy Moore) (USL)
Nelson - Phillips Oil Co
(Kraft)
Crawford & Files
Indian Oil Co "Placerita"
Standard Oil Co of Calif (Placerita)
Gulberson Oil Co (York)
Crawford & Files "Aqueduct"
Republic Pet Co
(Tunnel)
(Banner)
(Fink)
WHITNEY CANYON AREA
Republic Pet Co
Myers & Wilhite "Swall-Ferrier"
(Swall-Ferrier)
Calif Hansell Oil Co 1
NEWHALL
F E Fairfield "Road Ulrich" 1
R W Sherman "Newhall Comm"
R W Sherman "Almond"
Howard Pet Co
Rothschild Oil Co
TR
No
1079
1078
1274
Newhall
Aurora Corp "Braille"
SO Co of Cal
Richfield O Corp "Shepard"
Milan J Trumble "Henderson"
P B Anderson 2
Golden West 1
Kellerman 3
SCALE
2000
0
2000
4000
6000 FT.

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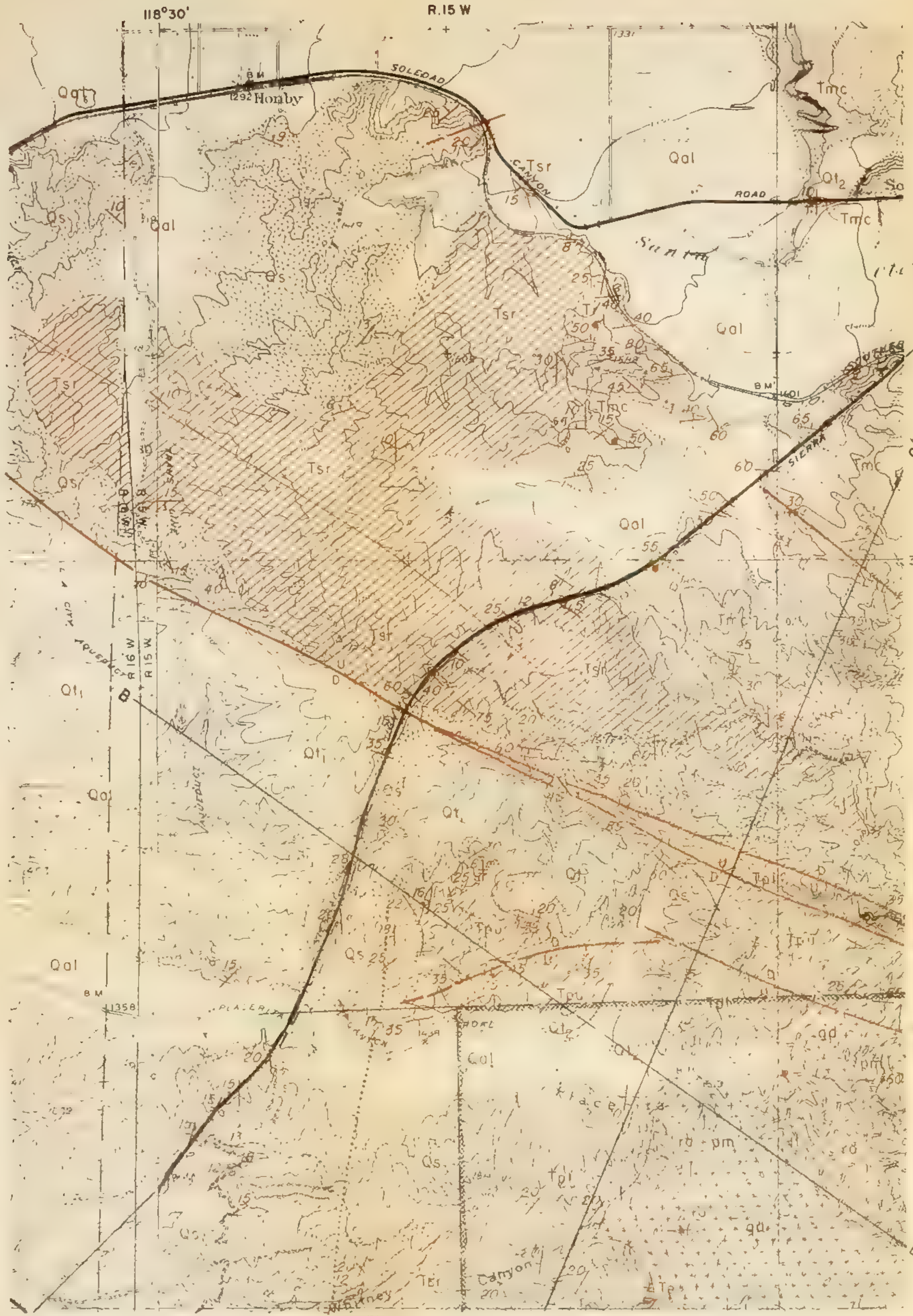

Base from parts of the Saugus, Humphreys, Newhall and Sylmar quadrangles

Geology by G B Oakeshott

TOPOGRAPHIC AND GEOLOGIC MAP OF THE

PLACERITA OIL FIELD

LOS ANGELES COUNTY, CALIFORNIA

SCALE
0 — 1 MILE

SEDIMENTARY ROCKS

			Symbol	Description	
QUATERNARY	Recent		Qal	Alluvium	
	Pleistocene	Upper	Qt₂	Later terrace deposits (fanglomerate and stream gravels.)	
			Qt₁	Older terrace deposits (fanglomerate and stream gravels.)	
		Lower	Qs	Saugus formation (continental conglomerate and sandstone; often little consolidated.)	
TERTIARY	Pliocene	Upper	Tsr	Sunshine Ranch member (continental greenish sandstone, mudstone, conglomerate, red beds and thin limestone beds.)	Pico formation
			Tpu	Upper Pico member (marine coarse to fine sandstone and mudstone, conglomerate; fossiliferous.)	
		Middle	Tpl	Lower Pico member (marine conglomerate and sandstone; massive fine sandstone and siltstone fossiliferrous calcareous sandstone.)	
		Lower	Tr	Repetto siltstone member (marine brown and gray siltstone and mudstone.)	Repetto formation
			Te	Elsmere member (marine fossiliferous, often petroliferous, coarse sandstone and conglomerate; interbedded medium and fine grained sandstone and siltstone.)	
	Miocene		Tmc	Mint Canyon formation (continental coarse gray and buff sandstone and conglomerate; brown and greenish sandstone; greenish mudstone; thin red sandstone and claystone beds; tuff beds; lake beds.)	

IGNEOUS AND METAMORPHIC ROCKS

		Symbol	Description
PRE-TERTIARY	Upper Jurassic ?	gd	Granite, granodiorite, monzonite.
	Paleozoic ?	rd pm	Rubio diorite gneiss and Placerita metasedimentary rocks.

GEOLOGIC SYMBOLS

Contacts
- definite trace
- uncertain trace

Faults
- definite trace
- apparent trace
- concealed

Axis of anticline showing plunge

Axis of syncline

Dip and strike
- determined
- approximate
- horizontal

Exposed oil sand

Fossil locality

Conglomerate bed

Tuff bed

Limestone

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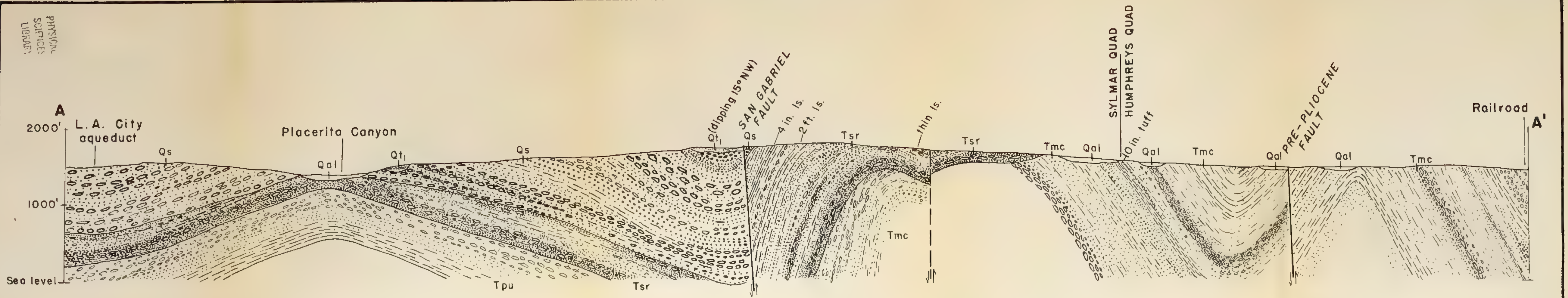
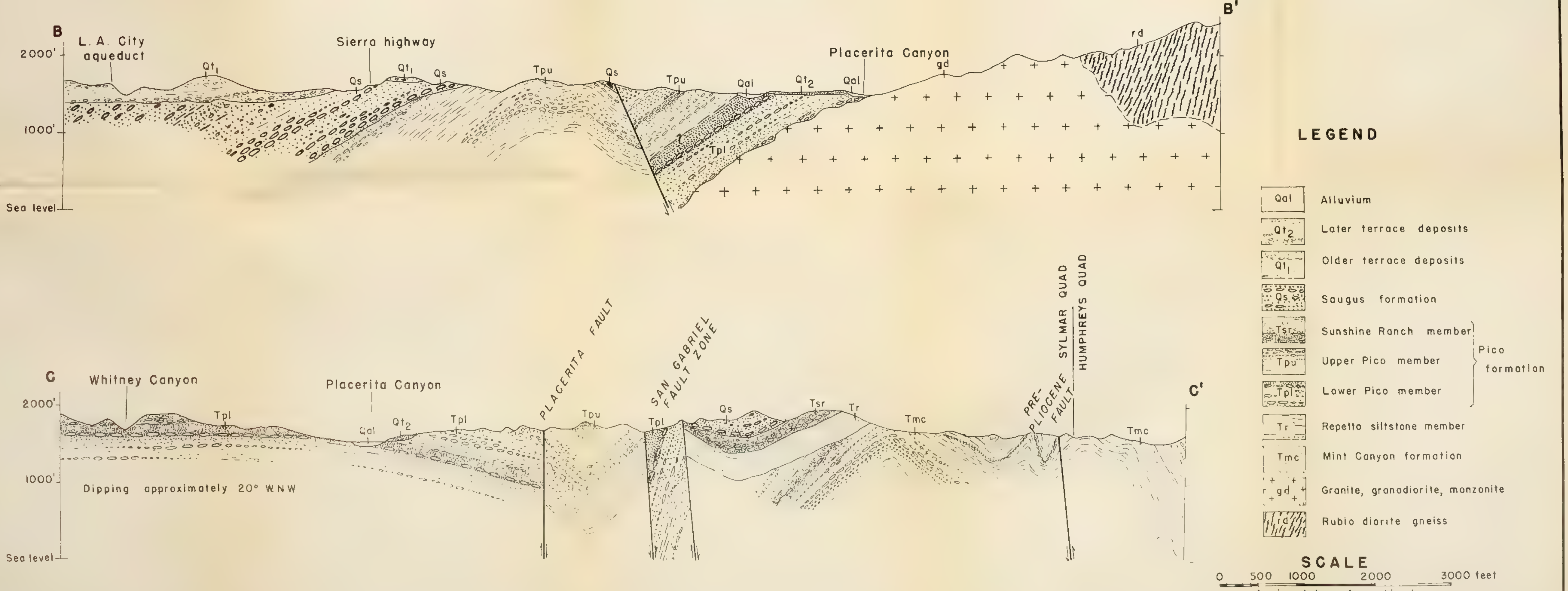

A
A'
2000'
1000'
Sea level
L. A. City aqueduct
Placerita Canyon
Qs
Qal
Qt1
Q(dipping 15°NW)
SAN GABRIEL FAULT
4 in. ls.
2 ft. ls.
Tsr
thin ls.
SYLMAR QUAD
HUMPHREYS QUAD
10 in. tuff
Tmc
PRE-PLIOCENE FAULT
Railroad
Tpu

SECTION A-A' ALONG SIERRA HIGHWAY


B
B'
2000'
1000'
Sea level
L. A. City aqueduct
Sierra highway
Qt1
Qs
Tpu
Qal
Qt2
Placerita Canyon
gd
rd
Tpl
C
C'
Whitney Canyon
Placerita Canyon
Tpl
Qal
Qt2
Tpu
Dipping approximately 20° WNW
PLACERITA FAULT
SAN GABRIEL FAULT ZONE
Qs
Tsr
Tr
Tmc
PRE-PLIOCENE FAULT
SYLMAR QUAD
HUMPHREYS QUAD
LEGEND
Qal Alluvium
Qt2 Later terrace deposits
Qt1 Older terrace deposits
Qs Saugus formation
Tsr Sunshine Ranch member
Tpu Upper Pico member
Tpl Lower Pico member
Pico formation
Tr Repetto siltstone member
Tmc Mint Canyon formation
gd Granite, granodiorite, monzonite
rd Rubio diorite gneiss
SCALE
0 500 1000 2000 3000 feet
horizontal and vertical

GEOLOGIC SECTIONS OF THE PLACERITA OIL FIELD
GORDON B. OAKESHOTT
1949

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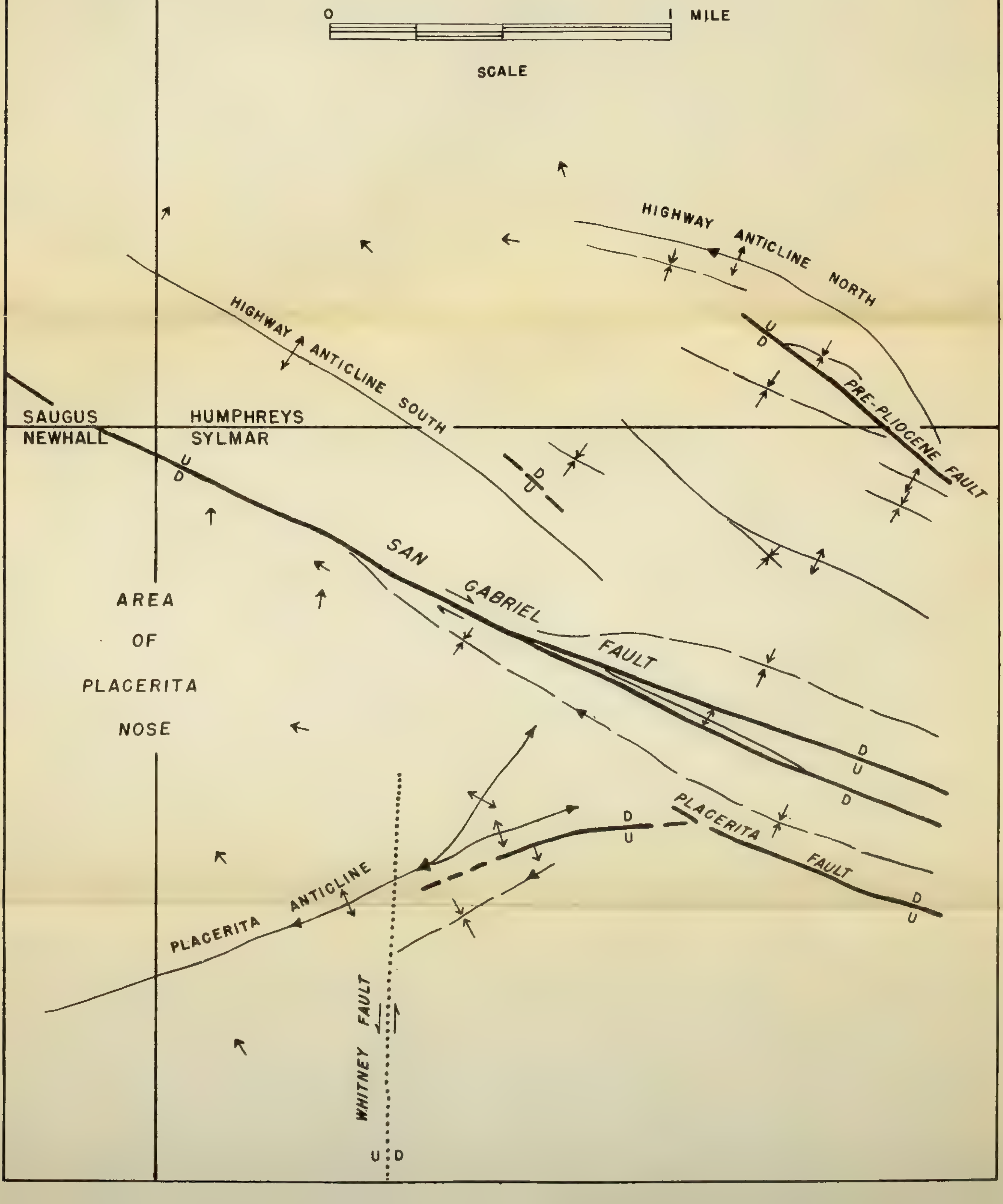
TECTONIC MAP
OF THE
PLACERITA OIL FIELD


0
1 MILE
SCALE
HIGHWAY ANTICLINE NORTH
HIGHWAY ANTICLINE SOUTH
PRE-PLIOCENE FAULT
SAUGUS
NEWHALL
HUMPHREYS
SYLMAR
SAN GABRIEL FAULT
AREA OF PLACERITA NOSE
PLACERITA FAULT
PLACERITA ANTICLINE
WHITNEY FAULT
U
D

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APRIL 1950

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Ironstone Concretions and Beach Ridges of San Diego County, California 213
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Mines and Mineral Resources of Alameda County, California 279

SUPPLEMENT

Manner of Locating and Holding Mineral
Claims in California

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO

STATE OF CALIFORNIA
EARL WARREN, Governor

DEPARTMENT OF NATURAL RESOURCES
WARREN T. HANNUM, Director

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Vol. 46 APRIL 1950 No. 2

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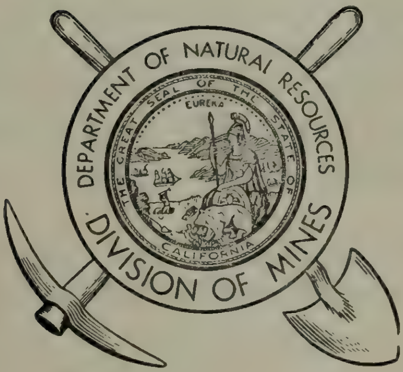

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BY FRANKLIN H. OLMSTED *

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ABSTRACT

The western San Jose Hills in Los Angeles County form a low upland which rises above the Quaternary alluvium of the San Gabriel River valley. The exposed rocks are folded Miocene and Pliocene sediments which are marginal facies of the rocks of the Los Angeles Basin. Data from several oil wells drilled in the area, and outcrops in the eastern San Jose Hills indicate that the Miocene sediments overlie middle Miocene volcanic rocks, which in turn overlie either pre-Upper Cretaceous coarsely crystalline plutonic and metamorphic rocks or a biotite dacite porphyry of pre-middle Miocene age.

Following the usage of previous workers in the region, the Pliocene rocks have been divided between the upper Pliocene Pico formation and the lower Pliocene Repetto formation. The upper Miocene Puente formation of Eldridge[1] and later workers has been divided into an upper and a lower member. The upper member includes the thin middle member of Woodford.[2]

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* Geologist, U. S. Geological Survey, Ground-water Branch, Sacramento, California.

[1] Eldridge, G. H., and Arnold, Ralph, The Santa Clara, Los Angeles, and Puente Hills oil fields: U. S. Geol. Survey Bull. 309, pp. 102-137, 1907.

[2] Woodford, A. O., Shelton, J. S., and Moran, T. G., Geology and oil possibilities of Puente and San Jose Hills, California: U. S. Geol. Survey, Oil and Gas Inv., Prelim. Map 23, 1944.

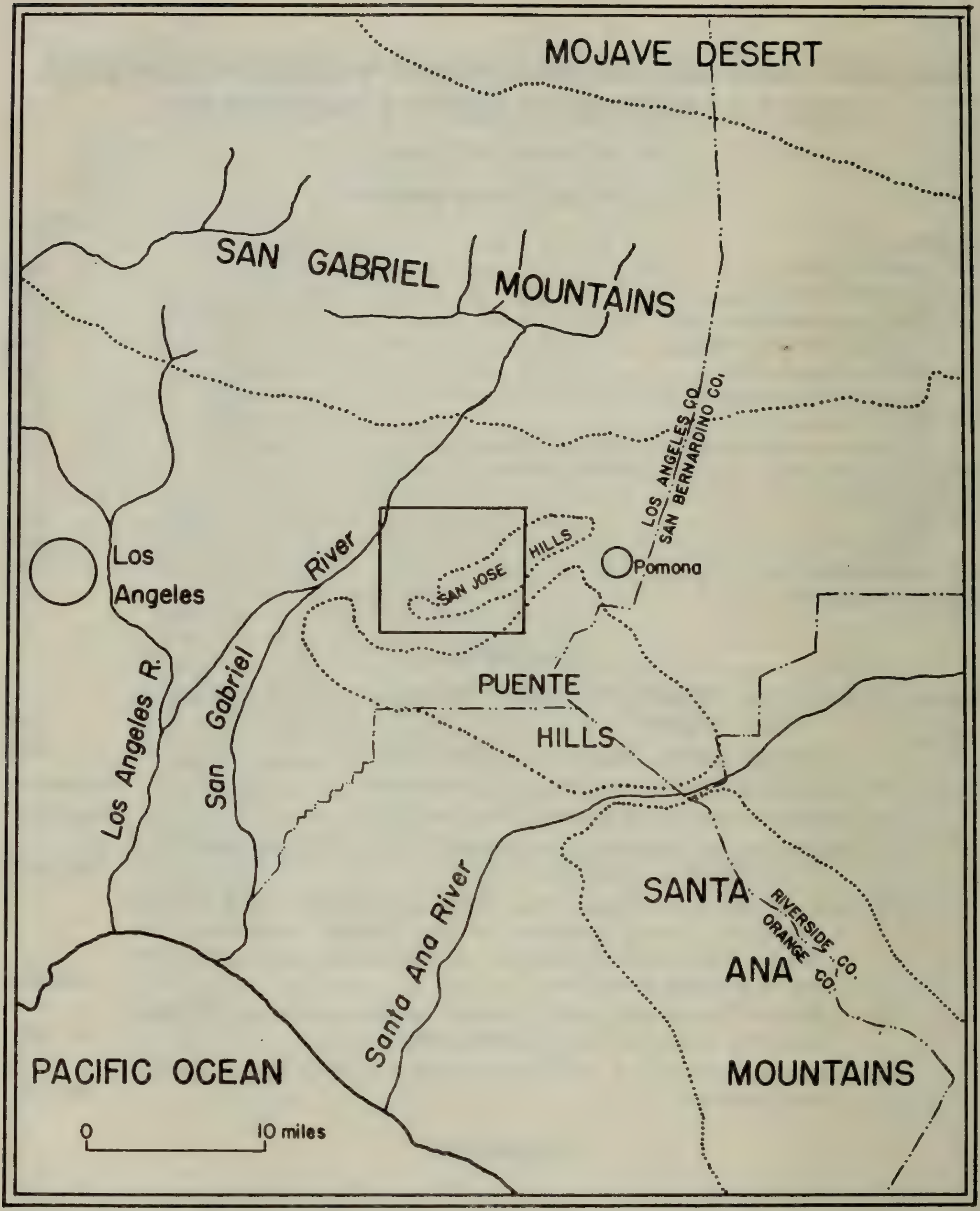
MOJAVE DESERT
SAN GABRIEL MOUNTAINS
LOS ANGELES CO.
SAN BERNARDINO CO.
Los Angeles
River
SAN JOSE HILLS
Pomona
PUENTE HILLS
Los Angeles R.
San Gabriel
Santa Ana River
SANTA ANA MOUNTAINS
RIVERSIDE CO.
ORANGE CO.
PACIFIC OCEAN
0
10 miles

Figure 1. Index map of part of southern California showing location of area mapped.

The structure in the western San Jose Hills consists essentially of two anticlines and an intervening syncline, all with axes trending approximately east. Faulting is not of great importance, and seems to be genetically related to the folding in most instances. Both anticlines have been tested by wildcat wells, some eighteen in number, but production has been achieved only in two wells in the western part of the southern anticline. The accumulation of oil here seems to be controlled in part by a fault which strikes at right angles to the anticlinal axis and has dropped the western block. The best prospects for future production seem to be on the southern anticline, west of this fault.

INTRODUCTION

Location of Area. The area described in this report is in Los Angeles County, about 25 miles east of Los Angeles. The Puente and San Jose Hills form a triangular upland region northwest of the Santa Ana Mountains, lying between the upper Santa Ana River valley, the San Gabriel Valley, and the coastal plain (see fig. 1). The San Jose Hills are separated from the Puente Hills by the valley of San Jose Creek, a small westward-flowing tributary of the San Gabriel River. The mapped area includes the San Jose Hills west of San Jose Hills Road and north of La Puente Road and Pomona Boulevard. The portion of the San Jose Hills west of Pass and Covina Road that is labelled "Puente Hills" on the Puente quadrangle of the U. S. Geological Survey will be referred to as the "Little Puente Hills" in this report.

Method of Study. The field work was begun in March 1947 and continued sporadically until August 1948. In July 1948, the writer, assisted by John G. Vedder, supervised a group of 11 field geology students at Pomona College, who mapped the entire area covered in this report except the Little Puente Hills. The writer subsequently checked most of this work in the field. Mapping was done on vertical aerial photographs made for the Agricultural Adjustment Administration in 1938. These photographs were enlarged to a scale of about 1 : 8000, so that ample detail could be shown where required. The data were later transferred from the photographs to the U. S. Geological Survey Puente and Covina quadrangles. Oil well core records, available from files in the Geology Department at Pomona College, were used to supplement outcrop data wherever possible.

Acknowledgments. The writer is grateful for the assistance of A. O. Woodford, Professor of Geology at Pomona College; J. S. Shelton, Assistant Professor of Geology at Pomona College; John G. Vedder of Claremont Graduate School; and the 11 participants in the 1948 field geology course at Pomona College. Manley L. Natland, micropaleontologist for the Richfield Oil Corporation, identified the foraminifera.

Previous Work. The following is a chronological list of the published works covering the Puente and San Jose Hills:

Eldridge, G. H., and Arnold, Ralph, The Santa Clara, Los Angeles, and Puente Hills oilfields: U. S. Geol. Survey Bull. 309, pp. 102-137, 1907.

Chaney, R. W., A fossil flora from the Puente formation of the Monterey group: Am. Jour. Sci., 5th ser., vol. 2, pp. 90-92, 1921.

English, W. A., Geology and oil resources of the Puente Hills region, southern California: U. S. Geol. Survey Bull. 768, 110 pp., 1926.

Johnson, H. B., and Warren, Van Court, Geological and structural conditions of San Gabriel Valley region: California Div. Water Resources, Bull. 5, pp. 73-100, 1927.

Eckis, Rollin, Geology and ground water storage capacity of valley fill; California Div. Water Resources, Bull. 45, 279 pp., 1934.

Edwards, E. C., Pliocene conglomerates of Los Angeles Basin and their paleographic significance: Am. Assoc. Petroleum Geologists Bull., vol. 18, pp. 786-812, 1934.

Krueger, M. L., The Sycamore Canyon formation, California (abstract): Am. Assoc. Petroleum Geologists Bull., vol. 20, p. 1520, 1936.

Ten Eyck, R. G., Late Tertiary foraminifera of San Jose Hills, Los Angeles County, California (abstract): Geol. Soc. America Proc. 1936, p. 364, 1936.

Bellemin, G. J., Petrology of Whittier conglomerates, southern California: Am. Assoc. Petroleum Geologists Bull., vol. 24, pp. 649-671, 1940.

Holman, W. H., Whittier oil field: California Div. Mines Bull. 118, pp. 288-291, 1943.

Krueger, M. L., Chino area: California Div. Mines Bull. 118, pp. 362-363, 1943.

Woodford, A. O., Shelton, J. S., and Moran, T. G., Geology and oil possibilities of Puente and San Jose Hills, California: U. S. Geol. Survey, Oil and Gas Inv., Prelim. Map 23, 1944.

Shelton, J. S., Geological map of northeast margin of San Gabriel Basin, Los Angeles County, California: U. S. Geol. Survey, Oil and Gas Inv., Prelim. Map 63, 1946.

Woodford, A. O., Moran, T. G., and Shelton, J. S., Miocene conglomerates of Puente and San Jose Hills, California: Am. Assoc. Petroleum Geologists Bull., vol. 30, pp. 514-560, 1946.

Some of these works are of special interest, because they deal directly with the area studied in this paper.

Eldridge named the Puente formation and divided it into the three members which have been widely used in mapping. However, his map of the western Puente Hills was very rudimentary and showed almost no structure.

English's paper included a map showing structure of the San Jose and Puente Hills. The old 1:62500 scale U. S. Geological Survey topographic maps were used as base maps. Although the ages of the formations shown in the Little Puente and western San Jose Hills must be modified on the basis of later studies, the structure is essentially correct, and the lithologic boundaries are well located. This work was the first serious attempt to map the Puente and San Jose Hills in any detail.

Eckis' groundwater paper contains geological maps with data taken from various published and unpublished works available at that time. The structure shown in the Little Puente and western San Jose Hills agrees essentially with English's map, but the ages of the formations were adjusted to conform with later usage.

The next detailed mapping in the western San Jose Hills, done by Woodford, Shelton, and Moran, was published in 1944. By this time, the use of foraminifera and fish scales in age determinations was more highly developed, and several important changes from the previous maps were made.

The paper published by Woodford, Moran, and Shelton in 1946 is a study of the source of the Miocene conglomerates in the San Jose and Puente Hills.

STRATIGRAPHY[3]

Basement Complex

Crystalline basement rock is exposed throughout the San Gabriel Mountains 5 to 10 miles north of the San Jose Hills, and is found in wells, beneath the Cenozoic sediments in the San Gabriel Basin, between the San Jose Hills and the San Gabriel Mountains. The major rock types include acidic intrusives of probable Mesozoic age, complex gneisses and schists which are older than the intrusives, and metasediments which may be Paleozoic. Rather extensive mylonite belts are exposed in the eastern San Gabriel Mountains.[4] The middle Miocene Topanga formation in the San Jose Hills contains pebbles and cobbles of mylonite exactly like the eastern San Gabriel Mountains types, so it is reasonable to assume that the crystalline rocks of the San Gabriel Mountains were undergoing erosion at least as early as middle Miocene time.

Crystalline basement rock has been found in wells in the Puente and San Jose Hills and in outcrops near Pomona. Two wells were drilled to basement rock in the western San Jose Hills. A pink granite gneiss was found in the Ohio Oil Company's Legrand No. 1 well at 5073 feet below sea level; and the Texas Company's Garnier No. 1 well more than 2 miles farther west encountered a quartz diorite protomylonite at 5600 feet below sea level.

A dacite porphyry, known locally as ''Mountain Meadows'' dacite porphyry, has been found in some wells in the San Jose and Puente Hills. It is exposed at the Mountain Meadows Country Club near the eastern end of the San Jose Hills, where it consists of euhedral phenocrysts of biotite and oligoclase and rounded quartz grains in a fine-grained groundmass. It is either a shallow intrusive or an extrusive, and it is evidently older than the middle Miocene Glendora volcanics, as pebbles of dacite have been found in the basal volcanics.[5]

Middle Miocene Rocks

The oldest sedimentary rocks cropping out in the San Jose Hills are exposed in the central part of the hills about a mile east of the mapped area. The dominant lithologic type in the outcrop is a poorly sorted conglomerate and conglomeratic sandstone which is locally called ''Buzzard Peak conglomerate.''[6] West of the exposed conglomerate, the Ohio Legrand No. 1 well and the Texas Garnier No. 1 well penetrated shale and sandstone of the Luisian and Relizian stages[7] at what appear to be the same horizons. Although the maximum thickness of the Buzzard Peak conglomerate is at least 2800 feet (based on well and outcrop data), very little conglomerate was found in the Ohio Legrand well less than a mile west of the outcrop, and the entire thickness of middle Miocene sediments is only 1800 feet in this well. These middle Miocene sediments, including

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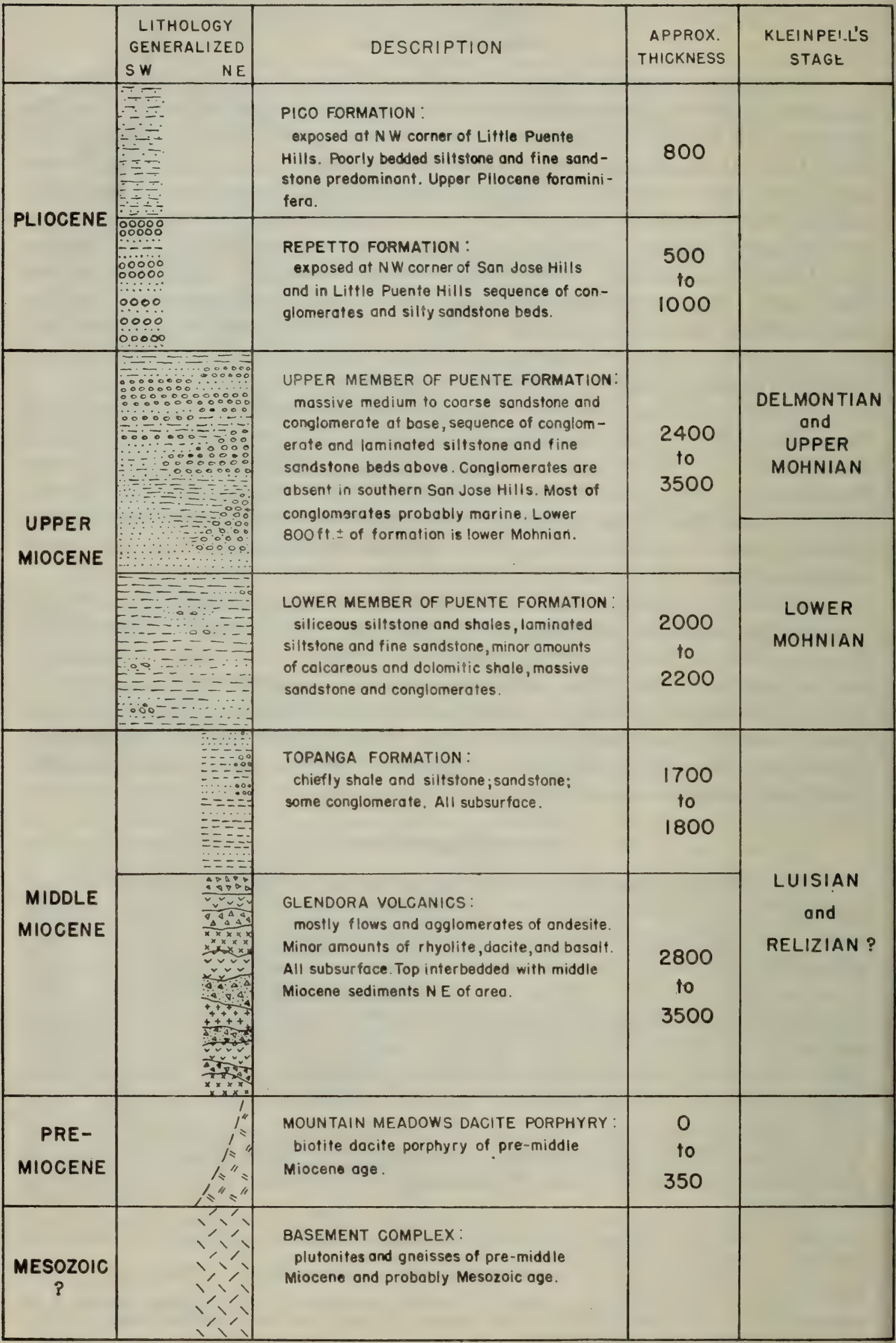
[3] In the nomenclature of sedimentary rocks, C. K. Wentworth's usage is followed. See his *A scale of grade and class terms for clastic sediments* published in Journal of Geology, vol. 30, pp. 377-392, 1922.

[4] Alf, R. M., Mylonites in the eastern San Gabriel Mountains: California Div. Mines Rept. 39, pp. 145-151, 1943.

[5] Shelton, J. S., Geological map of northeast margin of San Gabriel Basin, Los Angeles County, California: U. S. Geol. Survey, Oil and Gas Div., Prelim. Map 63, 1946.

[6] Woodford, et al., op. cit., 1944.

[7] Kleinpell, R. M., Miocene stratigraphy of California, 450 pp., Tulsa, Oklahoma, Am. Assoc. Petroleum Geologists, 1938.



	LITHOLOGY GENERALIZED SW NE	DESCRIPTION	APPROX. THICKNESS	KLEINPELL'S STAGE
PLIOCENE		PICO FORMATION: exposed at NW corner of Little Puente Hills. Poorly bedded siltstone and fine sandstone predominant. Upper Pliocene foraminifera.	800	
		REPETTO FORMATION: exposed at NW corner of San Jose Hills and in Little Puente Hills sequence of conglomerates and silty sandstone beds.	500 to 1000	
UPPER MIOCENE		UPPER MEMBER OF PUENTE FORMATION: massive medium to coarse sandstone and conglomerate at base, sequence of conglomerate and laminated siltstone and fine sandstone beds above. Conglomerates are absent in southern San Jose Hills. Most of conglomerates probably marine. Lower 800 ft.± of formation is lower Mohnian.	2400 to 3500	DELMONTIAN and UPPER MOHNIAN
		LOWER MEMBER OF PUENTE FORMATION: siliceous siltstone and shales, laminated siltstone and fine sandstone, minor amounts of calcareous and dolomitic shale, massive sandstone and conglomerates.	2000 to 2200	LOWER MOHNIAN
MIDDLE MIOCENE		TOPANGA FORMATION: chiefly shale and siltstone; sandstone; some conglomerate. All subsurface.	1700 to 1800	LUISIAN and RELIZIAN ?
		GLENDORA VOLCANICS: mostly flows and agglomerates of andesite. Minor amounts of rhyolite, dacite, and basalt. All subsurface. Top interbedded with middle Miocene sediments NE of area.	2800 to 3500	
PRE-MIOCENE		MOUNTAIN MEADOWS DACITE PORPHYRY: biotite dacite porphyry of pre-middle Miocene age.	0 to 350	
MESOZOIC ?		BASEMENT COMPLEX: plutonites and gneisses of pre-middle Miocene and probably Mesozoic age.		

FIGURE 2. Columnar section, western San Jose Hills.

the Buzzard Peak conglomerate, are probably correlative with the Topanga formation of the Santa Monica Mountains [8] and are so named here.

North and east of the Buzzard Peak region, the Topanga sediments overlie and are interbedded with volcanic flows and tuffs. Approximately 2800 to 3500 feet of these volcanics were found below the Topanga in wells in the western San Jose Hills. Shelton [9] has named these pyroclastics and flows the Glendora volcanics. Pebbles of the Glendora volcanics are very abundant in some upper Miocene conglomerates of the San Jose Hills.

Puente Formation

General Description. The Puente formation, which was named from the Puente Hills by Eldridge,[10] is upper Miocene, and is the approximate age equivalent of the upper part of the Monterey formation of other regions in California.[11] The Puente, as defined by Eldridge, is a sequence of clastic sediments ranging from shale to conglomerate, with various amounts of organic and siliceous shales of the Monterey type. The maximum known thickness of the formation in the Puente Hills has been estimated to be 9000 feet,[12] but the equivalent thickness in the San Jose Hills is between 4400 and 5700 feet.

Eldridge divided the formation into three members to facilitate mapping. A thick massive sandstone occurs near the middle of the sequence in the eastern Puente Hills, so this three-fold division seemed simple and reasonable.

The lithology of the members varies considerably, but the fine-grained sediments of the lower and upper members are typically more laminated and of smaller grain size than the massive medium-grained standstone of the middle member. All three members contain some conglomerate.

This subdivision has been used by most of the later workers in the region. Krueger,[13] however, found that the lower part of the conglomerate-bearing Fernando formation (Pliocene) in the westernmost Puente Hills north of Whittier was really upper Miocene (upper Mohnian and Delmontian stages of Kleinpell), and assigned a new name, Sycamore Canyon formation, to this sequence.

Woodford [14] used the lower-middle-upper member subdivision in the general map of the Puente and San Jose Hills. However, this division of the Puente formation is rather difficult to use in the San Jose Hills where the massive sandstone near the middle of the section is thin and interfingers with finer and coarser sediments in a confusing way.

The writer feels that a more natural and logical solution of the problem in the San Jose Hills is to use only the upper and lower members and place Wodford's thin middle Puente member at the base of the upper Puente.

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[8] Hoots, H. W., Geology of the eastern part of the Santa Monica Mountains, Los Angeles County, California: U. S. Geol. Survey Prof. Paper 165c, 134 pp., 1930.

[9] Op. cit.

[10] Op. cit.

[11] Bramlette, M. N., The Monterey formation of California and the origin of its siliceous rocks: U. S. Geol. Survey Prof. Paper 212, 57 pp., 1946.

[12] Woodford, et al., op. cit., 1944.

[13] Krueger, Max L., The Sycamore Canyon formation, California (abstract): Am. Assoc. Petroleum Geologists Bull., vol. 20, p. 1520, 1936.

[14] Op. cit., 1944.

Table 1. Upper Miocene Pebble Counts.

Locality	Description of location	No. feet above base of upper Puente	No. pebbles examined
P13	Site of McCartney Hurley No. 1 well, elev. 575 ft., Little Puente Hills. 10,770 ft. W, 7,290 ft. N of SE. corner of Puente sheet	2850	33
P10	8,000 ft. W, 7,620 ft. N of SE. corner of Puente sheet; elev. 705 ft., Little Puente Hills	2700	33
P12	10,280 ft. W, 6,570 ft. N of SE. corner of Puente sheet; elev. 495 ft., Little Puente Hills	2600 (?)	34
P7	9,310 ft. W, 7,650 ft. N of SW. corner of Puente sheet; elev. 550 ft., Little Puente Hills	2400	33
P11	4,290 ft. W, 13,580 ft. N of SE. corner of Puente sheet; elev. 590 ft., San Jose Hills	1750 (?)	33
P9	2,660 ft. W, 15,920 ft. N of SE. corner of Puente sheet; elev. 555 ft., San Jose Hills	1150	50
P8	2,080 ft. W, 12,460 ft. N of SE. corner of Puente sheet; elev. 630 ft., San Jose Hills	1000	33
P6	3,300 ft. W, 14,040 ft. N of SE. corner of Puente sheet; elev. 550 ft., San Jose Hills	930	50

	Percentage at								
Rock type	P6	P8	P9	P11	P7	P12	P10	P13	Average
Mica-quartz-feldspar plutonite	25	25	26	19	24	26	34	25	25½
Actinolite-quartz-feldspar plutonite	6	3	0	0	6	3	0	0	2
Alaskite	3	0	8	12	2	15	3	3	6
Pegmatite	0	6	0	6	0	3	3	0	2
Aplite	12	12	8	15	6	6	12	6	9½
Dacite porphyry	0	3	8	0	2	12	3	9	5
Total plutonites and dike rocks	46	49	50	52	40	65	55	43	50
Mica-quartz-feldspar orthogneiss	12	9	10	15	6	12	18	27	13½
Mica-hornblende-quartz-feldspar gneiss	0	0	0	0	0	0	0	3	½
Mica-(feldspar)-quartz paragneiss	3	18	8	3	12	9	12	6	9
Quartz-hornblende-biotite schist	0	0	0	3	0	0	0	0	½
Quartzite	0	6	2	0	10	0	0	0	2
Total metamorphic rocks	15	33	20	21	28	21	30	36	25½
Total Basement Complex Types	61	82	70	73	68	86	85	79	75½
Andesite, andesite porphyry, basalt	15	6	14	15	16	14	6	6	11½
Dacite, quartz latite, rhyolite	0	3	4	0	0	0	3	6	2
Rotten volcanic rock	24	9	14	12	16	0	6	9	11
Total Glendora Volcanics Types	39	18	32	27	32	14	15	21	24½

Lower Member. All of the lower member of the Puente formation in the western San Jose Hills belongs in Kleinpell's lower Mohnian substage. The thickness, indicated from wells and outcrop, is about 2000 to 2200 feet, and consists mainly of siliceous fine-grained rocks, with some partings of clastic sediments, beds of impure limestone or dolomite, and small amounts of massive sandstone and conglomerate.

The most abundant type is a finely banded porcelaneous siltstone and shale with pairs of laminae as thin as about 0.1 millimeter. Some of the rock breaks into rectangular slabs, with one fracture plane parallel to the bedding and the other two perpendicular. The lithology is of the high-silica type of Monterey, as described by Bramlette.[15]

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[15] Op. cit.

Throughout most of the lower member, thin beds of clastic siltstone and fine sandstone are intercalated with the siliceous rocks. Locally this material becomes more abundant than the porcelaneous siltstone and shale and may form zones of well-laminated siltstone and fine sandstone as much as several feet in thickness.

In at least two places, both of them near the axis of the San Jose anticline and therefore low in the section, lenses of massive, fine- to coarse-grained sandstone as much as 350 feet in thickness occur in isolated bodies in the finer-grained sediments. The lateral gradation from siltstone and shale into sandstone is in most places strikingly abrupt, although the sandstone body south of Hills 1268 and 1296 grades into laminated siltstone and fine sandstone and then into porcelaneous siltstone on its western margin. In most cases the vertical gradation is also abrupt, probably indicating a sudden but very local change in depositional environment.

The abundance of carbonate beds and concretions is a striking feature. The beds, almost all between 10 inches and 3 feet thick, are gray, buff, or yellow-brown in color, and range in composition from nearly pure limestone or dolomite to calcareous fine sandstone. These strata recur at fairly regular intervals throughout the section, and their stratigraphic separation is seldom less than 10 feet. The carbonate concretions form ellipsoidal masses up to several feet across in the porcelaneous siltstone and shale.

A general estimate of the relative abundance of the lithologic types in the lower Puente in the western San Jose Hills, based on the best exposures seen, is: siliceous and porcelaneous siltstone and shale, 50 percent; laminated clastic siltstone and fine sandstone, 30 percent; massive, medium-grained sandstone, 10 percent; calcareous and dolomitic rocks, 10 percent.

Upper Member. The upper member of the Puente formation, as defined in this report, corresponds to Woodford's middle and upper members of the Puente formation in the San Jose Hills.[16] Generally speaking, the upper Puente in the western San Jose Hills consists of a basal unit of massive medium- to coarse-grained sandstone and conglomerate, which is equivalent to Woodford's middle Puente member; and a sequence of fine-grained sediments and conglomerates, which is equivalent to Woodford's upper Puente member. The maximum thickness, based on surface and subsurface data, is 3500 feet in the Little Puente Hills and 2400 feet at the western end of the San Jose Hills proper.

The basal sandstone varies considerably in thickness and character. It is about 970 feet thick in the McCartney Hurley No. 1 well in the Little Puente Hills, and becomes thinner east of this point. Massive sandstone 125 feet thick is exposed on the west nose of the San Jose anticline, where the outcrop consists chiefly of dip slopes developed on the more indurated horizons. As the sandstone is traced farther east, it thickens again and becomes coarser and even conglomeratic. Most, if not all, of this thickening is caused by an eastward coarsening in the overlying finer-grained sediments. The base of the sandstone and conglomerate seems to remain at about the same horizon. The maximum thickness of interbedded sandstone and conglomerate in the eastern part of the mapped area is about 900 feet, on both the south and north limbs of the

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[16] See also Woodford, A. O., et al., op. cit., 1944.

San Jose anticline. Apparently all of this, with the possible exception of the highest conglomerate, is lower Mohnian. The basal sandstone appears to be missing on the south limb of the Little Puente Hills anticline, where clastic siltstone and fine sandstone directly overlie lower Puente porcelaneous siltstone and shale.

Most of the sandstone is massive and medium grained, with subangular to subrounded grains of quartz, feldspar, biotite, and muscovite. Fresh surfaces are gray to white, while weathered surfaces are apt to be anything from dark brown to light gray, depending on the amount of iron oxide stain.

A considerable amount of well cemented very coarse sandstone occurs in the eastern area. The sandstone grades into granule conglomerate, through which are scattered boulders up to 3 feet across. The relative scarcity of clasts of pebble size, compared to the stratigraphically higher conglomerates, is curious. Most striking of the larger boulders are a purplish-red vesicular andesite or basalt and a peculiar very hard tourmaline-actinolite quartz plutonite.[17]

The sediments overlying the basal sandstone and conglomerate consist of a sequence of conglomerates and fine-grained clastic rocks, except in the southernmost part of the area, where conglomerate is lacking. This sequence, except for the lower 300 or 400 feet, is mostly upper Mohnian, though some of the nonfossiliferous strata near the top of the formation may be Delmontian.

Most of the fine-grained sediments are well-laminated clastic siltstone and fine sandstone, with a minor amount of porcelaneous siltstone and shale immediately above the massive sandstone on the west nose of the San Jose anticline. The clastic siltstone and fine sandstone are rhythmically bedded in pairs of laminae ranging from an eighth of an inch to 2 inches in thickness. The siltstone is medium to dark gray when fresh and light gray to white on weathered surfaces. This contrasts strongly with the buff or yellow color of the fine sandstone, giving the rock a banded aspect. Grains of muscovite, biotite, quartz, feldspar, and clay minerals can be distinguished with a hand lens, but some of the siltstone grades into shale, in which none of the mineral grains can be identified with certainty.

Not all of the fine sediments are well laminated. Some of the higher beds are characterized by fine sandstone with the hackly fracture and absence of bedding which is more typical of the Pliocene rocks.

The conglomerates which lie above the basal sandstone-conglomerate unit are typically well sorted and poorly cemented. Locally the cementation may be strong enough to permit vertical exposures of conglomerate several feet high. On the north limb and around the west nose of the San Jose anticline the lowest conglomerate in this sequence is remarkably uniform in thickness and general lithologic character; it can be traced from Cameron Avenue at the northeast corner of the mapped area southwestward as far as Hill 807 near the Supreme Dairy. It disappears south and west of here, however, and it is not found in the Shell Garnier No. 1 well, nor in the Little Puente Hills. The higher conglomerates are less uniform in thickness along the strike, but they persist into the Little

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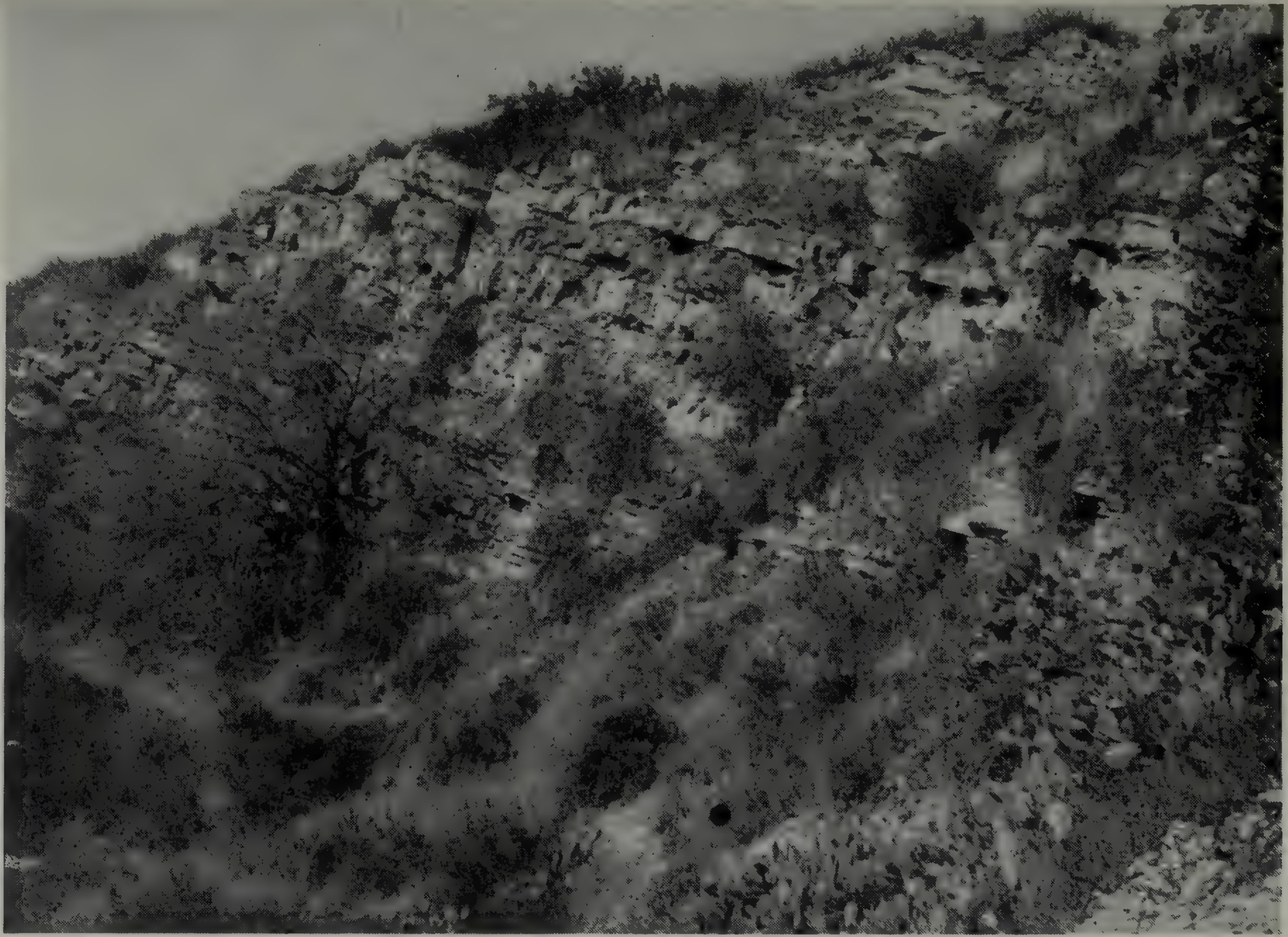
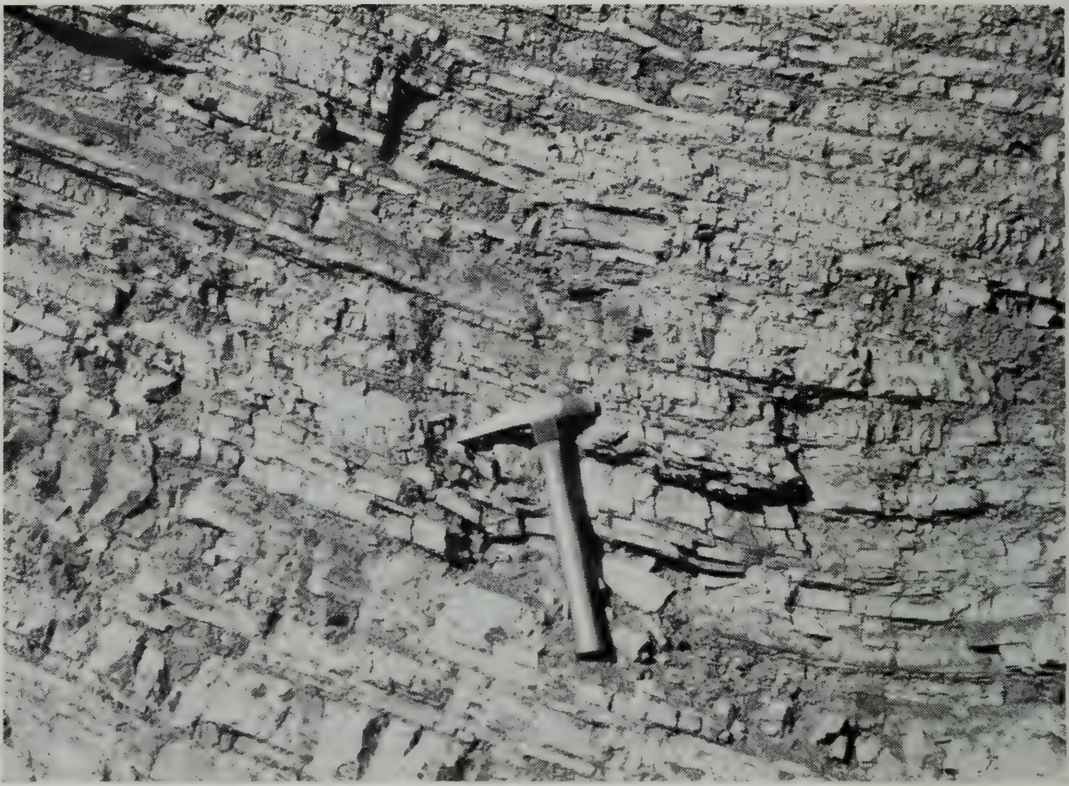
[17] See also Woodford, A. O., Moran, T. G., and Shelton, J. S., Miocene conglomerates of Puente and San Jose Hills, California: Am. Assoc. Petroleum Geologists Bull., vol. 30, p. 526, 1946.

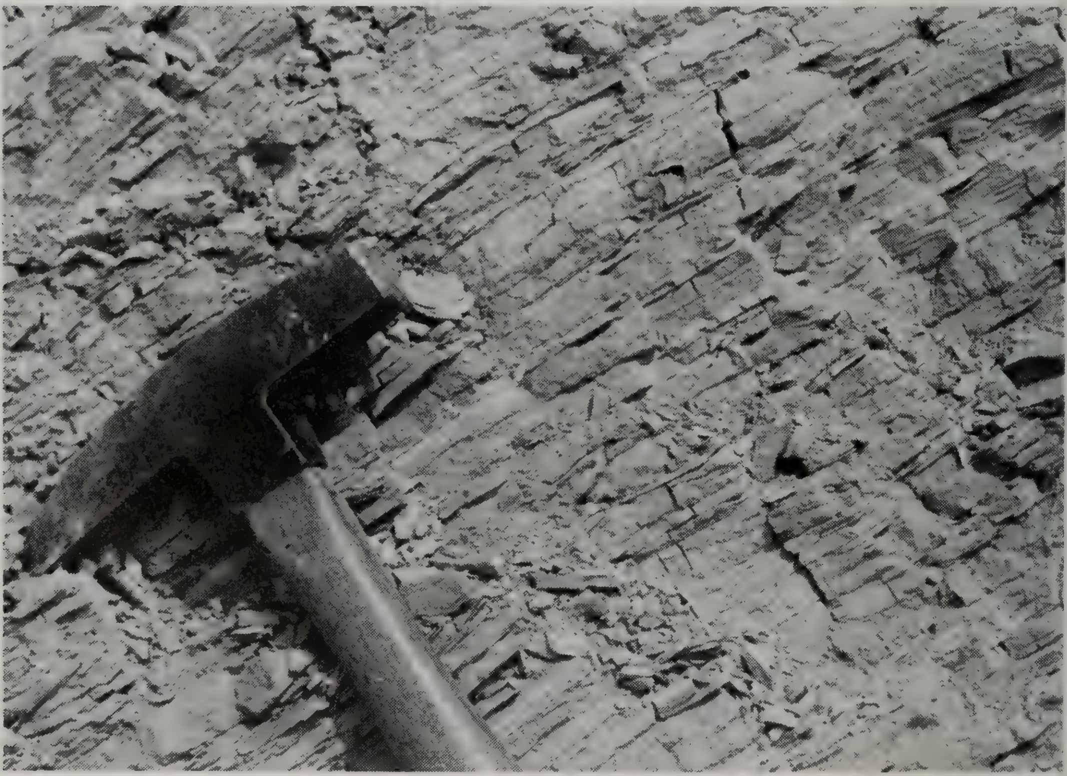


SANDSTONE AND INTERBEDDED CONGLOMERATE
UPPER MEMBER, PUENTE FORMATION

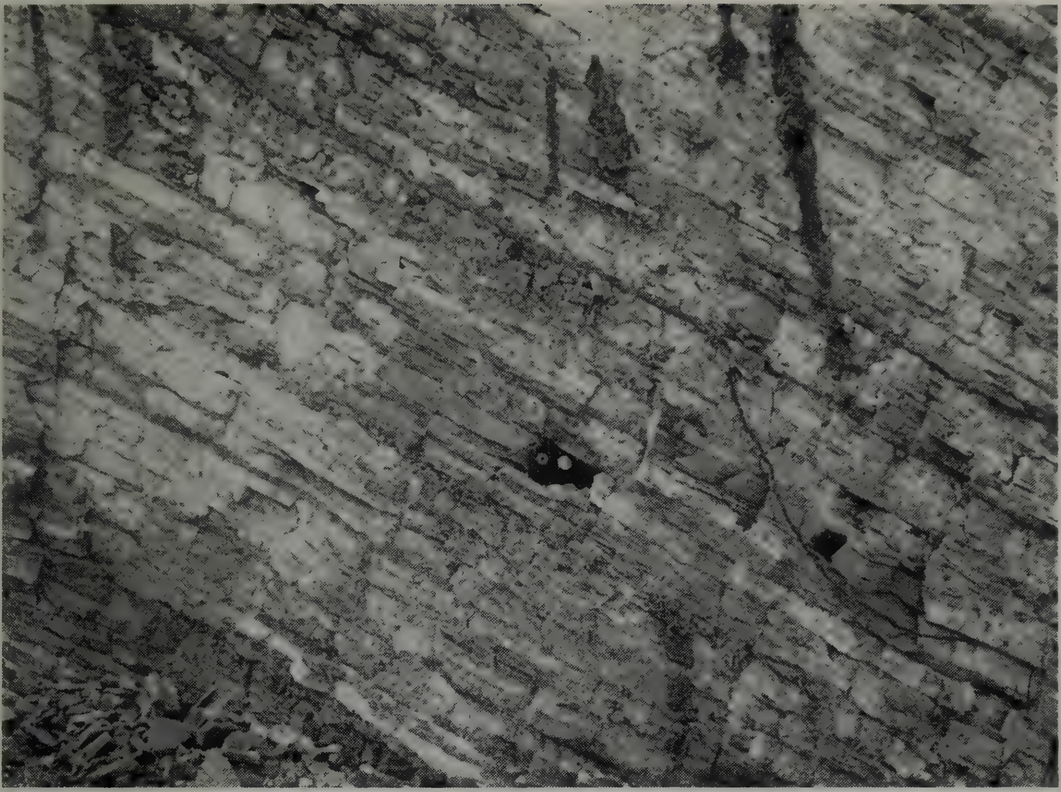
The hard, well-bedded, medium to coarse sandstone with some interbedded conglomerate is typical of the lower part of the upper member of the Puente formation, in the eastern part of the mapped area. This exposure is on the north limb of the San Jose anticline.



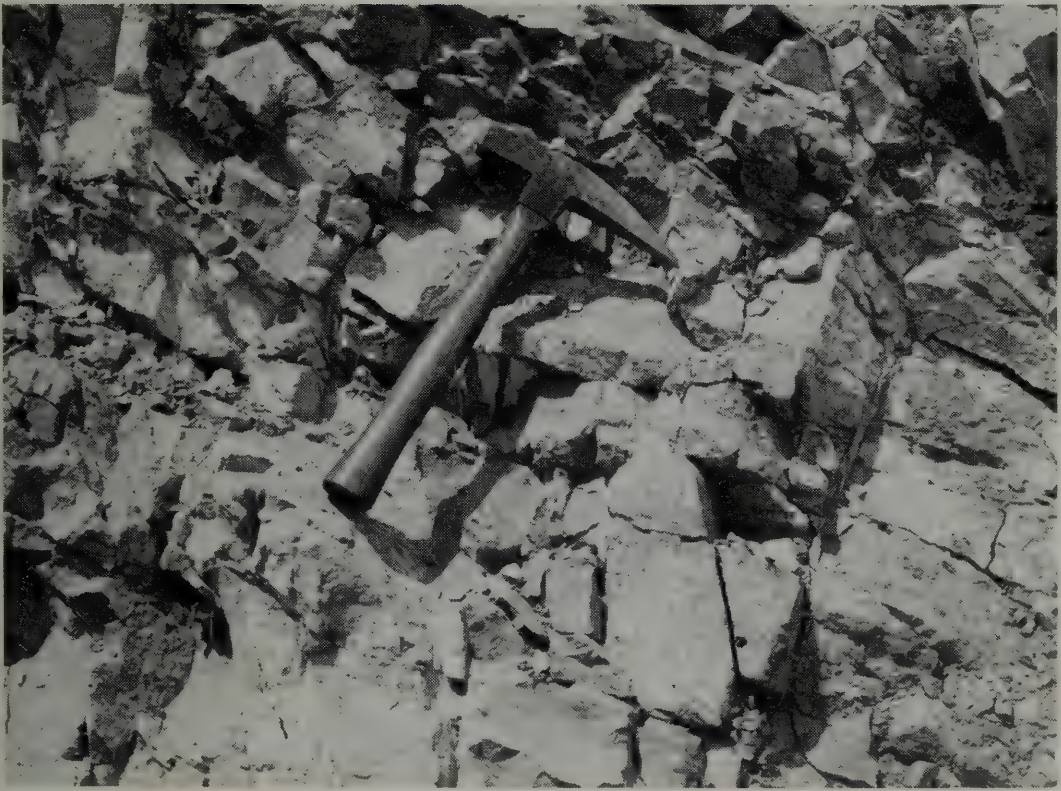
A, PORCELANEOUS SILTSTONE AND SHALE INTERBEDDED WITH IMPURE LIMESTONE
Lower member of Puente formation. Exposed in road cut on San Jose Hills Road.



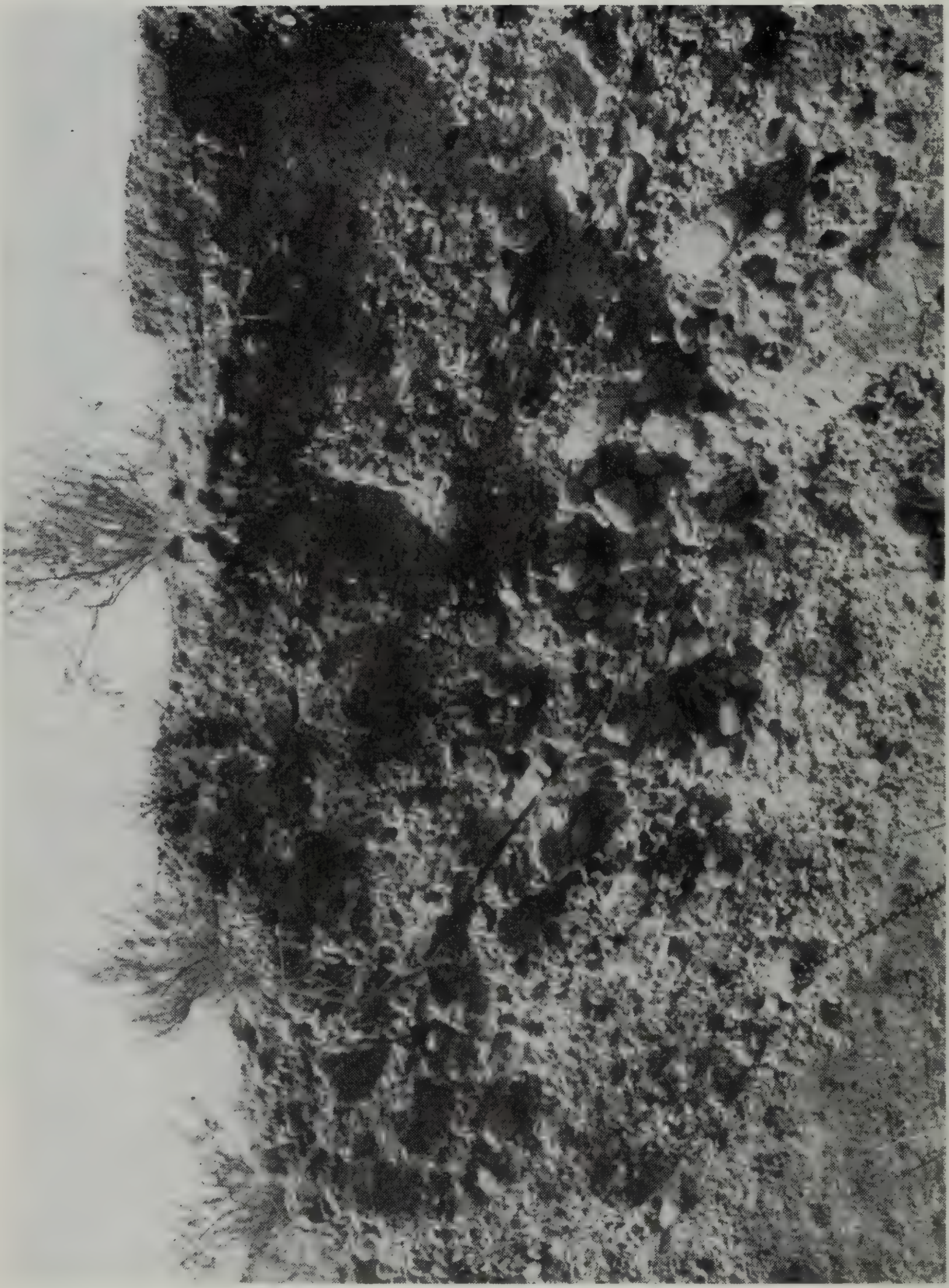
B, RHYTHMICALLY BEDDED SILTSTONE AND FINE SANDSTONE
Upper member of Puente formation. Exposed in road cut at fossil locality F5, in western San Jose Hills.



A, UPPER PUENTE LAMINATED SILTSTONE AND FINE SANDSTONE
Near Hill 954, western San Jose Hills. Key case gives the scale.



B, MASSIVE SILTY SANDSTONE OF PICO FORMATION
Northwestern Little Puente Hills. Note contrast in lithology with upper Puente shown in above photograph.



VERTICAL EXPOSURE OF WELL-SORTED AND CEMENTED CONGLOMERATE

Upper member of the Puente formation in northwestern San Jose Hills. Bedding can be distinguished by size sorting of pebbles and cobbles, and by occasional beds of sandstone.

uente Hills, where they become very thick and extensive. None of these nglomerates is present in the southernmost part of the San Jose Hills.

Probably the most striking single feature of the upper Puente conomerates is the presence of numerous cobbles and boulders of a very rd, pale green and lavender colored tourmaline-actinolite granite or artz monzonite.[18] This rock typically contains orthoclase (or microine), albite, quartz, actinolite, and in some cases, tourmaline. Some of e boulders are quite large; the largest found was 48 by 32 by 30 inches d was estimated to weigh more than 1 ton. Evidently most of this rock as removed from the source area by erosion before the Pliocene, as few ulders of it are found in the Pliocene conglomerates, and none is known occur in any of the possible source regions today.

Repetto Formation

The name Repetto formation was proposed in 1930 by a committee the Pacific Section of the Society of Economic Paleontologists and Minalogists to apply to the siltstone of lower Pliocene age exposed in the epetto Hills east of Los Angeles.[19] The type locality is on the west side Atlantic Boulevard in the Repetto Hills, where a section of siltstone out 2000 feet thick is exposed. The lower part of the formation is not posed here, but is found half a mile to the west, as about 500 feet more siltstone.

The maximum thickness of Repetto exposed in the Puente Hills rth of the Whittier fault is 2700 feet.[20] The lithology here is coarser an in the type area to the west, and there are several thick conglomerate ses.

In the Little Puente and western San Jose Hills, the Pliocene-Mioe contact cannot be established on faunal evidence. The entire quence of strata between the upper Mohnian locality F17 at Hill 654 the western San Jose Hills, and locality F19 of upper Pliocene age the northwestern Little Puente Hills, is barren of diagnostic foraminra. In the Puente Hills to the south and west, across the valley of San se Creek, fossiliferous Repetto overlies the upper Puente conformably, d fossiliferous upper Pliocene Pico lies on the Repetto with appart conformity.[21] There, the Repetto consists of sandy, micaceous siltne with hackly fracture and lack of bedding lamination, alternating th lenses of conglomerate. This lithology is well developed in the Little ente Hills, and, although fossils are lacking, it seems reasonable to sign at least some of the sequence below the fossiliferous upper Plioe to the Repetto formation.

Inasmuch as both the lower and upper boundaries of the Repetto the Little Puente Hills had to be selected arbitrarily, the most promit lithologic breaks, which could be traced for a considerable distance ng the strike, were chosen. The lower boundary (Pliocene-Miocene) s placed at the base of the conglomerate that forms the principal eastst drainage divide. The upper boundary was placed at the top of the hest conglomerate.

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[18] See also Woodford, A. O., op. cit., 1946.

[19] Reed, R. D., Section from the Repetto Hills to the Long Beach oil field: Int. Geol. g., 16 sess., Guidebook 15, Excursion C-1, Southern California, p. 31, 1932.

[20] Woodford, A. O., and Daviess, S. N., Stratigraphy and structure of northwestern nte Hills, California: U. S. Geol. Survey Oil and Gas Inv., Prelim. Map 83, 1949.

[21] Woodford and Daviess, op. cit.

There is some justification for the selection of the particular P
cene-Miocene contact chosen in the Little Puente Hills. Most of the c
glomerates and fine-grained sediments lower in the section are v
lenticular and show very abrupt lateral gradation in grain size. The c
tact between this conglomerate and the underlying fine sandstone b
by contrast, can be traced throughout the Little Puente Hills with li
or no change in stratigraphic position. Moreover, there is a verti
change in the lithology of both the conglomerates and the fine-grai
sediments, which, although it is gradational, is definite enough to
significant. All of the upper Puente conglomerate beds contain vari
amounts of the distinctive tourmaline-actinolite quartz monzonite
granite. No cobbles or boulders of this type of granite have been fou
above the arbitrary Pliocene-Miocene contact in the Little Puente Hi
and very few are present in the highest conglomerate in the northwest
San Jose Hills. None of the fine-grained sediments mapped as Repe
has the fissility and thin laminated character of the upper Puente be
Here, again, the vertical change is gradational, but the gradation ta
place in the sediments below the arbitrary contact.

Table 2. Pliocene Pebble Counts.

Locality	Description of location	No. feet above base of Pliocene	N pebb exam
P5	12,490 ft. W, 8,570 ft. N of SE. corner of Puente sheet; elev. 600 ft., Little Puente Hills	500	6
P4	10,720 ft. W, 5,910 ft. N of SE. corner of Puente sheet; elev. 512 ft., Little Puente Hills	?	5
P3	6,240 ft. W, 15,480 ft. N of SE. corner of Puente sheet; elev. 490 ft., San Jose Hills	150	10
P2	9,580 ft. W, 8,980 ft. N of SE. corner of Puente sheet; elev. 735 ft., Little Puente Hills	60	5
P1	11,640 ft. W, 8,310 ft. N of SE. corner of Puente sheet; elev. 630 ft., Little Puente Hills	30	3

Rock type	Percentage at P1	P2	P3	P4	P5	Ave
Mica-quartz-feldspar plutonite	37	30	30	40	52	38
Alaskite	0	10	4	12	0	5
Pegmatite	3	0	1	0	4	1
Aplite	9	16	17	12	18	14
Dacite porphyry, granodiorite porphyry	6	0	5	10	3	5
Total plutonites and dike rocks	55	56	57	74	77	64
Mica-quartz-feldspar orthogneiss	9	26	19	--	4	11
Hornblende-quartz-feldspar orthogneiss	3	0	3	--	0	1
Mica-(feldspar)-quartz paragneiss	12	8	8	--	7	7
Undifferentiated gneiss	--	--	--	18	11	6
Total metamorphic rocks	24	34	30	18	22	25
TOTAL BASEMENT COMPLEX TYPES	79	90	87	92	99	8
Andesite, andesite porphyry, basalt	21	2	5	8	0	7
Dacite, quartz latite, rhyolite	0	4	7	0	1	2
Rotten volcanic rock, unidentifiable	0	4	1	0	0	1
TOTAL GLENDORA VOLCANIC TYPES	21	10	13	8	1	10

It is possible that the highest conglomerate exposed east of the Shell rnier No. 1 well, which is located just west of Pass and Covina Road, Pliocene. Tourmaline-actinolite-quartz plutonite cobbles and boulders e very rare in this conglomerate, and the lithology is otherwise very nilar to the lithology of the conglomerates assigned to the Repetto in the ttle Puente Hills.

The Repetto formation, as mapped in the Little Puente Hills, consists siltstone beds alternating with fine sandstone and conglomerate beds ich vary considerably in thickness along the strike. The siltstone and e sandstone are traceable as beds for some distance along the strike, d as lenses within the conglomerate. The siltstone is predominantly ndy and micaceous. Quartz, biotite, muscovite, feldspar, and clay min- als can be seen with a hand lens. Weathered surfaces are light gray or ff in color; fresh surfaces are light to medium brown. The cementation usually poor. Stratification is seldom visible, except where finer-grained ds of siltstone are present. The rock is nearly always irregularly frac- red, and white caliche fills many of the cracks.

A section, measured with tape and Brunton compass on the first ridge rthwest of Hill 806 in the Little Puente Hills, gave a thickness of about 0 feet for the Repetto. Roughly half of this thickness is conglomerate; remainder is poorly bedded, soft, silty sandstone. As shown on the ologic map, most of the sandstone lenses out to the west, around the nose the Little Puente Hills anticline. East of the measured section, the ckness of Repetto increases to about 1000 feet.

Repetto Section in Little Puente Hills

(Measured on ridge on north flank of hills, immediately west of Hill 806)

of section	Thickness (feet)
ssive, buff to gray silty fine sandstone. Biotite flakes abundant. Foraminifera of lower Pico age (upper Pliocene) found 400 feet above the base of this sandstone at locality F19, which is about half a mile west of the measured section. Base of this sandstone arbitrarily taken as base of the Pico and top of the Repetto	(Top not exposed)
glomerate. Mostly well sorted; rounded and subrounded pebbles average less than 3 inches in diameter, are fairly well cemented in a medium to coarse sandy matrix. Pebbles and cobbles are predominantly plutonic and metamorphic rocks, but volcanics are common	65
e gray sandstone, with a few thin beds of conglomerate. Sandstone is micaceous, highly fractured, poorly bedded, and soft. Conglomerates are composed of well-rounded pebbles	95
e sandstone and conglomerate. Pebbles and cobbles are generally more abundant than in above; otherwise same lithology	71
ssive, hard, fine gray sandstone. Contains from 5 to 10 percent biotite and abundant altered feldspar grains and clay minerals. Cementing material is somewhat calcareous	2
y to yellowish fine sandstone. Micaceous, highly fractured, poorly bedded, and soft	117
glomerate. Mostly poorly sorted; pebbles and cobbles subrounded, up to 6 inches in diameter. Volcanic pebbles not uncommon. Matrix coarse, sandy, poorly cemented	31
bly fine sandstone. Pebbles sparse at top, becoming much more abundant near base. Sandstone is fine-grained, buff-colored, micaceous, highly fractured, poorly bedded, and soft	101
glomerate. Fairly well sorted, with many small pebbles. Volcanic pebbles estimated to make up about 10 percent of total	45
al thickness	527

Pico Formation

The Pliocene rocks in the coastal region of southern California we included in the Fernando group of Pliocene and Pleistocene age by Hom Hamlin.[22] In 1924, W. S. W. Kew divided the Pliocene deposits on t north side of the San Fernando Valley into two formations; the lower w called the Pico, the upper the Saugus. The Pico was assigned to the low Pliocene on the basis of fossils. It lies unconformably on the upper Mioce Modelo formation in this region.[23] More recently, the Pico has be restricted to upper Pliocene.[24] A fossil locality in the Pico near the Ha dorf Dairy in the northwestern Puente Hills has yielded upper Plioce foraminifera as well as numerous megafossils. The maximum thickn of the Pico in the northwestern Puente Hills is approximately 1400 feet No clear evidence of unconformity with the underlying Repetto f mation has been discovered in the area.

In the absence of diagnostic fossils lower in the section, the base the Pico has been arbitrarily placed just above the uppermost co glomerate in the northwestern Little Puente Hills. The exposed thickn of the formation is about 790 feet.

The Pico sediments in the Little Puente Hills are, for the most pa homogeneous fine sandstones and siltstones. A sandy, micaceous siltsto predominates. As in the Repetto, the bedding is very indistinct, a can be distinguished only by the thin partings of finer-grained siltsto Where these partings are absent, it is very difficult to ascertain the at tude of the bedding. The rock is brown on fresh surfaces, and weathers mottled light gray and buff. The important minerals are muscov biotite, quartz, feldspar, and clay minerals probably derived from fe spar. The rock is poorly cemented, and highly fractured. Caliche f many of the joints and fractures. The soil that developed from this ro is a dark brown loam which supports a growth of wild oats and grass

Quaternary Alluvium and Terrace Deposits

Undeformed and poorly consolidated alluvium and terrace depo of recent and probable late Pleistocene age cover the older rocks on margins of the hills. No attempt has been made to differentiate the a vium and the older terrace deposits on the geologic map, as this distinct is of no importance for the purpose of this report.

SOURCE OF THE CONGLOMERATES

Woodford, Moran, and Shelton,[26] in their paper on the Mioc conglomerates of the Puente and San Jose Hills, concluded that the m likely source region of the conglomerates extended from the western Gabriel Mountains eastward in a 120-degree arc to the southeastern Gabriel Mountains, and possibly to the Perris block.

In order to cast more light on this problem, pebble counts w made at 13 localities in the Little Puente and western San Jose Hills, me of the typical San Gabriel Mountains rock types were examined egascopically and microscopically. The general procedure outlined by ellemin [27] was followed in making each pebble count. Table 1 sum- arizes the results at the eight upper Puente (later upper Miocene) alities; table 2 lists the data for the five Repetto (lower Pliocene) alities. All of the localities are on the Puente quadrangle and are ranged in approximate stratigraphic sequence in each table.

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[22] Unpublished manuscript. See Eldridge and Arnold, op. cit.

[23] Kew, W. S. W., Geology and oil resources of a part of Los Angeles and Ven Counties, California: U. S. Geol. Survey Bull. 753, 202 pp., 1924.

[24] Hoots, H. W., General geology of the Los Angeles Basin: Int. Geol. Cong., sess., Guidebook 15, Excursion C-1, Southern California, p. 24, 1932.

[25] Woodford and Daviess, op. cit.

[26] Op. cit., 1946.

The results of the investigations support Woodford's [28] conclusions to the source of the conglomerates. In addition to fairly numerous bbles of the Mt. Waterman granite of Arnold and Strong,[29] the writer und such diagnostic types as Mountain Meadows dacite porphyry [30] d a very distinctive type of hornblende andesite porphyry, which is own to occur as a dike rock in the eastern San Gabriel Mountains.

The extreme scarcity of mylonite pebbles is a perplexing problem. ylonite is an abundant rock in the eastern San Gabriel Mountains, and is very well represented in the middle Miocene Buzzard Peak conglo- rate. Possibly the source region for the upper Miocene and lower iocene conglomerates of the Little Puente Hills and westernmost San se Hills did not extend quite as far east as the present mylonite areas.[31]

The scarcity of hornblende-bearing plutonites and orthogneisses in conglomerates is another interesting problem. An examination of pebbles and cobbles sampled at random from Recent detritus in San tonio wash, about 15 miles northeast of the Little Puente Hills, showed t hornblende-bearing orthogneisses and plutonites made up 38 per- t of the total, while similar rocks comprise but 1 percent of the total the 13 conglomerate localities. This disparity might be explained by amlette's theory of the instability of hornblende in sedimentary ks.[32]

Comparisons of the ratios of basement complex rock types to Glen- ra volcanics types at the various localities reveal an important fact: e proportion of volcanic rocks generally decreases, going up in the tion. The average proportion of volcanic rocks is 10½ percent of the al for the five Repetto localities, but it is 24½ percent for the eight per Puente localities. At one upper Puente locality in the northeastern rt of the mapped area, volcanic rocks make up more than 80 percent the total. In general, at any given horizon, the proportion of volcanic ks increases northeastward. This might be expected, as most of the sent outcrops of Glendora volcanics are northeast of the Little Puente d western San Jose Hills.

STRUCTURE

Folds

Folds, rather than faults, are the dominant structural features of western San Jose Hills. Two anticlines and an intervening syncline, trend generally eastward. They are the northern, or San Jose anticline (the San Jose Hills anticline of English[33]) ; the southern, or Lit Puente Hills anticline; and the Amar syncline, named from Amar Ro In addition to these three major folds, there are a few small folds minor importance.

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[27] Bellemin, G. J., Petrology of Whittier conglomerates, southern California: Am. oc. Petroleum Geologists Bull., vol. 24, pp. 649-671, 1940.

[28] Op. cit., 1946.

[29] Arnold, Ralph, and Strong, A. M., Some crystalline rocks of the San Gabriel untains, California: Geol. Soc. America Bull., vol. 16, pp. 183-204, 1905. See also lemin, G. J., op cit.

[30] Shelton, J. S., op. cit.

[31] See Alf, R. M., op cit.

[32] Bramlette, M. N., The stability of minerals in sandstone: Jour. Sedimentary rology, vol. 11, no. 1, pp. 32-36, 1941.

San Jose Anticline. The San Jose anticline is the most importa structural feature of the western San Jose Hills. This fold is clea shown topographically by the main high mass of the hills. The crest this anticline, which follows closely the principal drainage divide, broad and gently undulating, and has been located only approximat on the geologic map. The bearing of the axis at the eastern end of mapped area is about N. 65° E. Westward, the axis curves gently nor ward, so that west of Hill 1268, the bearing is almost due east.

The San Jose anticline is strongly asymmetric at the easte boundary of the mapped area. Here, the north limb is gently inclin with dips averaging 25 degrees. The south limb is steeper and is cut abruptly by a steep fault, along which the southern block has be dropped. Farther west the fold is still asymmetric, but the fault on south limb has probably changed to a sharp flexure instead of an act break. Still farther west, the anticline becomes more symmetrical a starts to form the broad nose at the western end of the hills. The n axis has a westward plunge of about 30 degrees.

Amar Syncline. Like the San Jose anticline, the Amar synclin asymmetric in the east, with a steep north limb and gentle south lir and becomes symmetrical and westward-plunging farther west. The we ward plunge begins about half a mile east of the Supreme Dairy a steepens to 20 degrees at the Dairy. The synclinal axis is half to thr quarters of a mile south of the San Jose anticline axis, and closely p allels it. The trough of the syncline appears to continue west of P and Covina Road, passing north of the Little Puente Hills beneath alluvium.

Little Puente Hills Anticline. The western part of the Lit Puente Hills anticline is revealed topographically by the Little Pue Hills, but it is less clearly revealed farther east, in the San Jose Hi The eastern end of the anticline is a broad nose which plunges eastw at 15 to 30 degrees. The western end of the anticline in the Little Pue Hills plunges westward at an angle of about 30 degrees.

Throughout most of its extent the Little Puente Hills anticlin symmetrical, but it is overturned southward at the east end of the Li Puente Hills. Here the dips of both the north and south limbs are ab 55 degrees, indicating a 55-degree northward dip of the axial pla Associated with this overturning is a sharp southeastward bend in axis, which suggests lateral pressure from the north, east of the bend the axis.

Minor Folds. A small anticline and syncline lie between the Ar syncline and the Little Puente Hills anticline in the vicinity of Chanslor-Canfield Midway Oil Company Sentous No. 1 and Bard Puente No. 1 wells. The exact position of the axes of these folds is im sible to determine because of the poor exposures, but the C. C. M. O. seems to have been located near the axis of the anticline, which ha northwest bearing here. Actually, this structure may be considered a double crest on the Little Puente Hills anticline, the northern c disappearing to the west.

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[33] Op. cit.

The "wrinkle" on the nose of the San Jose anticline southwest of l 1078 is another minor fold. This small fold, which in part accounts the strange outcrop pattern here, is strikingly shown by a limestone just above the upper Puente sandstone, which changes in attitude m N. 65° E., 30° SE. to N. 25° W., 55° SW. in a distance of less than feet along the strike.

The brittle and incompetent porcelaneous shale and siltstone beds he lower Puente are locally highly contorted. Attitudes taken at iso- ed outcrops are usually unreliable; consequently only attitudes that w persistent areal trends in the lower Puente are shown on the geo- ic map.

Faults

San Jose Fault. Evidence for most of the faults in the Little Puente l western San Jose Hills is unfortunately indirect and often very cure. Perhaps the best marked and most important is the San Jose lt which drops the south limb of the San Jose anticline near the eastern der of the mapped area. The steep escarpment on the south side of main east-west drainage divide is the principal topographic expres- n of the fault; other evidence includes a brecciated zone of porcela- us shale blocks and caliche, and sudden steepening of dips and local rturning near the fault zone. There is no positive evidence of the ount of displacement, but all indications are that it decreases west- rd and finally changes to a sharp flexure. The fault plane seems to nearly vertical. The fault trace strikes about N. 60° E., or nearly allel to the axis of the San Jose anticline. The movement on the fault probably been vertical, the south block being downthrown.

Little Puente Hills Fault. The southern margin of the Little Puente ls may be determined by a west-striking fault which has dropped the th block. This fault apparently passes through the gap between the n mass of the hills and two low knolls to the south in the western a. The relative movement is inferred from the fact that Repetto ology is found on top of Knoll 512, whereas if the Little Puente Hills icline were not faulted, the trend of the beds would bring upper ente strata to this position. If it is assumed that the top of Knoll 512 ear the base of the Repetto, the displacement is between 600 and 800 t. In the absence of evidence to the contrary, it is assumed that the lt surface is vertical and that movement has been vertical.

Other Faults in Little Puente Hills. At least one fault is associated h the sharp bend in the axis of the Little Puente Hills anticline in the t-central Little Puente Hills. This fault seems to branch out from the tle Puente Hills fault 2000 feet south of Hill 728. The strike of the lt is about N.45°W., or parallel to the bend of the axis. The displace- nt does not seem to be large and dies out northwestward. The south- tern block is downthrown.

There is a discrepancy between the data obtained from the McCart- Hurley No. 1 well and the Bardeen Crittenden No. 1 well in the tral Little Puente Hills. The lower 700 feet of conglomerate in the Cartney Hurley well cannot be accounted for by the width of outcrop l dip of the exposed conglomerate to the east of the well. This problem ld possibly be solved by extending the fault discussed in the preceding agraph northwestward between the two wells, were it not for one fact:

the base of the massive sandstone of the upper Puente is stratigraphicall 700 feet higher in the McCartney well than in the Bardeen well. If th displacement on the hypothetical fault is to account for the lower 700 fe of conglomerate in the McCartney well, the base of the upper Puent sandstone should be 700 feet lower in this well, not 700 feet highe Invoking facies changes or sudden flexures in folding between the tw wells does not make the problem easier to solve.

Pass and Covina Fault. The Pass and Covina fault is anoth example of a fault whose existence can scarcely be doubted, but who details are difficult to work out. Its location is not precisely known, but seems to be marked approximately by Pass and Covina Road, between th Little Puente and San Jose Hills. The conglomerate beds on the north lim of the Little Puente Hills anticline are laterally offset to the south, west the fault, while the conglomerate on the south limb is offset to the nort This indicates that the western block is downthrown. This fault will discussed further under the heading *Oil prospects,* in connection with th explanations for the accumulation of oil in the eastern Little Puente Hill

Minor Faults. Favorable exposures often show minor faultir which would otherwise pass unnoticed. Most of the faults so revealed ha displacements measured in a few inches or feet and are therefore unir portant in the general picture. No attempt has been made to show ar of these faults on the geologic map.

OIL PROSPECTS

Oil Wells. The western San Jose Hills have been explored for since about 1917. The exploration work has been done largely by sm independent companies, but Shell Oil Company, Richfield Oil Corp ration, The Texas Company, and Ohio Oil Company have each drill one or two wells. The Bardeen Oil Company which has done the mo drilling, has six wells in the area.

Table 3 is a brief summary of the wells drilled in the Little Puen and western San Jose Hills. Records of some of the older wells are inco plete, and the information listed for these is only fairly reliable.

Production. Most of the wells have been commercially unprod tive, though many of them have found small amounts of oil and gas. T Bardeen Oil Company's No. 1 (Crittenden) well, drilled in 1922, whi produced 1600 barrels, and the same company's Lautenbach well, drill in 1948, are the only two wells with any appreciable production reco Both of these wells were drilled in the Little Puente Hills, on the crest the Little Puente Hills anticline.

Table 3. List of oil wells in western San Jose Hills and Little Puente Hills

No.	Operator	Well	Year begun	Year aband.	Elev.	Total depth	Remarks
1.	Bardeen Oil Co.	No. 1	1922	1927	535	4095	TP 1600 bbls. fr 1900′. Also known Crittenden well.
2.	Bardeen Oil Co.	No. 2	1925?		438	1645	Also known as Did or Pass-Covina well.
3.	Bardeen Oil Co.	No. 3	1925	1928	500	2250	Also known as Mall well.
4.	Bardeen Oil Co.	Puente No. 1	1930	1930	450	5001	Good core record. D 1150′ from vert.
5.	Bardeen Oil Co.	Puente No. 2	1930	1931	635	3000	Also known as Ber dette well. Good c record.

6.	Bardeen Oil Co.	Lautenbach	1948		475		Prod. from 1500′.
7.	D & B Oil Co.	No. 1	1926	1932	390	4520	
8.	C.C.M.O. Oil Co.	Sentous No. 1	1917	1918?	610	3953	
9.	J. C. Drilling Co.	Kelso No. 1	1939?		525	3505	Electric log.
10.	Julian & Criswell	Koch Community No. 1	1936		625	2965	Cored 810-2460; 2700-2730.
11.	McCartney, C. E.	Hurley No. 1	1943?		575	3259	Electric log. Good cores below 2000.
12.	McVicar-Rood	Sentous No. 1	1936	1936	620	3050	Good cores; good oil showings.
13.	Ohio Oil Co.	Legrand No. 1	1944		1068	6141	Good cores; no oil showings.
14.	Rancho de la Puente Oil Co.	No. 1	1923		540	4416	
15.	Richfield Oil Corp.	Didier No. 1	1928?		491	4486	Probably drifted from vertical.
16.	Shell Oil Co.	Garnier No. 1	1942	1942	403	4591	Electric log, good cores.
17.	Shell Oil Co.	Sentous No. 1	1920	1921	1162	3652	No oil showings.
18.	Tase Oil Co.	No. 1			540		
19.	The Texas Co.	Garnier No. 1	1944	1945	1180	7143	Good cores; no oil showings.

Conditions for Oil Accumulation. The western San Jose Hills are on the margin of the late Tertiary Los Angeles Basin and have a thinner and coarser series of sediments than the oil-producing regions near the center of the basin. Most of the Pliocene sediments, which are of such great importance as reservoir rocks in the large oil fields in the basin, have been eroded off the western San Jose Hills. Any oil accumulation is therefore restricted to sands and broken shales in the upper and middle Miocene.

The structural conditions for oil accumulation are fairly favorable. The Little Puente Hills anticline is closed on the west and on the east. The western part of the anticline is cut off from the eastern end by the north-trending Pass and Covina fault, which has dropped the west block. This may account for the production in the Bardeen Oil Company's Crittenden and Lautenbach wells, and the lack of production in the wells to the east of the fault. The producing horizons are confined mainly to the basal sandstone of the upper member of the Puente formation. This sandstone is probably faulted against impervious rocks at the Pass and Covina fault. The sandstone crops out east of the Pass and Covina fault, though the outcrop thickness is considerably less than the thickness encountered in the Bardeen Pass and Covina well just west of the fault. Lensing of the sandstone is probably responsible for some showings in the wells east of the fault.

Promising oil and gas showings were found in thick sands of the lower Puente in the McVicar-Rood Sentous No. 1 well, and to a lesser degree in the Julian and Criswell Koch Community No. 1 well, on the eastern part of the Little Puente Hills anticline. Low permeability of the sands probably accounted for the lack of production in these wells.

The San Jose anticline has been tested by four wells in the mapped area. The Shell Oil Company's Garnier No. 1 well encountered a small amount of sand, probably at the base of the upper Puente, at a depth of about 3800 feet. The Shell Sentous No. 1, The Texas Company Garnier No. 1, and the Ohio Legrand No. 1 farther east all started in lower Puente and found only minor sands in the lower Puente member and Topanga formation. It is not likely that commercial quantities of oil will ever be found on the San Jose anticline, but it is possible that some oil has accumulated south of the San Jose fault at the eastern end of the mapped area.

Table 4. San Jose Hills Foraminifera Localities Determined by Manley L. Natland

Locality	Description
F1	13,140 ft. N, 1,000 ft. W of S.E. corner of Puente quadrangle; in a ravine at an elevation of 680 ft., San Jose Hills. Most of sample *Globigerina bulloides*; some *Bolivina californica* (?). Probably lower Mohnian.
F2	5,130 ft. N, 2,400 ft. W of S.E. corner of Puente quadrangle; on east side of hill 501, at an elevation of 435 ft., San Jose Hills. *Bolivina sinuata, Buliminella curta, Globigerina bulloides, Discorbinella valmonteensis.* Not older than top of lower Mohnian, probably upper Mohnian.
F3	14,270 ft. N, 1,720 ft. W of S.E. corner of Puente quadrangle; on dirt road, at an elevation of 690 ft., San Jose Hills. *Globigerina bulloides, Buliminella subfusiformis, Bolivina vaughani, Bolivina californica.* Lower Mohnian.
F4	13,620 ft. N, 1,920 ft. W of S.E. corner of Puente quadrangle; on dirt road, at an elevation of 600 ft., San Jose Hills. Sample is probably at least as old as upper Mohnian.
F5	13,460 ft. N, 2,080 ft. W of S.E. corner of Puente quadrangle; on dirt road, at an elevation of 575 ft., San Jose Hills. *Globigerina bulloides* abundant, *Bolivina vaughani, Bolivina* sp. Probably at least as old as upper Mohnian.
F6	7,660 ft. N, 1,750 ft. W of S.E. corner of Puente quadrangle; at an elevation of 600 ft., San Jose Hills. *Bolivina vaughani, Globigerina bulloides, Buliminella subfusiformis, Bolivina californica.* Lower Mohnian.
F7	3,410 ft. E, 17,750 ft. N of S.W. corner of Covina quadrangle; in a ravine, at an elevation of 750 ft., San Jose Hills. *Bulimina uvigerinaformis, Buliminella curta.* Lower Mohnian.
F8	15,550 ft. N, 2,930 ft. E of S.W. corner of Covina quadrangle; at an elevation of 1,000 ft., San Jose Hills. *Bolivina californica*, et al. Probably lower part of lower Mohnian.
F9	16,320 ft. S, 10,430 ft. E of N.W. corner of Covina quadrangle; on the San Jose Hills Road, at an elevation of 730 ft. Lower Mohnian.
F10	15,920 ft. N, 1,400 ft. W of S.E. corner of Puente quadrangle; in a ravine, at an elevation of 600 ft., San Jose Hills. *Bolivina sinuata, Bolivina californica, Bolivina woodringi, Bolivina advena, Globigerina bulloides.* Lower Mohnian.
F11	12,940 ft. N, 2,100 ft. E of S.W. corner of Covina quadrangle; in a small ravine, at an elevation of 900 ft., San Jose Hills. Mostly *Bulliminella curta*; usually lower Mohnian.
F12	4,570 ft. N, 7,400 ft. E of S.W. corner of Covina quadrangle; at an elevation of 550 ft., San Jose Hills. *Discorbinella valmonteensis.* Probably upper Mohnian.
F13	13,420 ft. N, 1,690 ft. E of S.W. corner of Covina quadrangle; on dirt road, at an elevation of 1,100 ft., San Jose Hills. *Globigerina bulloides, Bolivina vaughani.* Nothing diagnostic.

F14 13,800 ft. N, 14,110 ft. E of S.W. corner of Covina quadrangle; at an elevation of 850 ft., San Jose Hills.
Bolivina californica, Uvigerina hootsi.
Lower Mohnian.

F15 13,200 ft. N, 12,500 ft. E of S.W. corner of Covina quadrangle; at an elevation of 735 ft., San Jose Hills.
Uvigerina perigrina, Uvigerina hootsi, Planulina ornata, Bolivina sinuata (small), *Valvulineria arikana, Cassidulina* aff. *crassa.*
Probably lower Mohnian.

F16 13,160 ft. N, 980 ft. W of S.E. corner of Puente quadrangle; about 35 ft. N.E. of locality F1, San Jose Hills.
Bulimina uvigerinaformis (small), *Bolivina californica, Pulvinulinella gyroidinaformis, Suggrunda pygmaea, Globigerina bulloides.*
Lower Mohnian.

F17 14,850 ft. N, 4,280 ft. W of S.E. corner of Puente quadrangle; at an elevation of 620 ft., San Jose Hills.
Upper Mohnian.

F18 14,210 ft. N, 1,600 ft. W of S.E. corner of Puente quadrangle; on dirt road, at an elevation of 700 ft., San Jose Hills.
Globigerina bulloides (most of sample), *Globorotalia canariensis, Bolivina vaughani.*
Nothing diagnostic, but probably lower Mohnian.

F19 9,400 ft. N, 13,270 ft. W of S.E. corner of Puente quadrangle; at an elevation of 480 ft., Little Puente Hills.
Textularia sp. "*flinti*," *Robulus cushmani, Bolivina spissa, Bolivina sinuata* (large), *Uvigerina peregrina, Pulvinulinella pacifica, Cassidulina californica, Cassidulina* "*crassiformis*," *Cassidulina cushmani, Cassidulina translucens, Pullenia quinqueloba, Cibicides* sp. "*cicatricosa*" (?).
Top of lower Pico.

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IRONSTONE CONCRETIONS AND BEACH RIDGES OF SAN DIEGO COUNTY, CALIFORNIA

By K. O. Emery[*]

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ABSTRACT

Ironstone concretions are very abundant in sands of beach ridges in San Diego County but are absent in the intervening areas. The ridges appear to be transverse sand dunes that accumulated along shorelines of the sea when it retreated from the Linda Vista terrace. The concretions formed after some weathering had occurred but before streams had dissected the ridges.

INTRODUCTION

Since first encountering them in 1937, the writer has been interested in the nature and origin of the ironstone concretions that are very abundant locally in San Diego County, California. An early but brief description of the concretions was given by Fairbanks.[1] Later, Scott,[2] Hanna,[3] and Hertlein and Grant [4] also mentioned them in reports on the geology of parts of the county. Whenever time permitted, the writer made intermittent investigations in order to learn whether or not the concretions were related to a former marine environment during an earlier time of greater submergence of the coast. Interesting relationships with physiography were soon apparent, and they form part of the basis of this report.

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[*] University of Southern California, Los Angeles, California. Manuscript summitted for publication September 8, 1949.

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Most of the mechanical analyses were made by Mr. Robert Stone; most of the iron oxide determinations were made by Mr. Robert Stevenson in the sediment laboratory of Allan Hancock Foundation of the University of Southern California.

GEOLOGICAL ENVIRONMENT

The concretions were found only on the Linda Vista terrace. This terrace was cut during the late Pliocene or early Pleistocene across poorly consolidated Eocene and Pliocene shales, sandstones, and conglomerates which dip a few degrees toward the south or southeast. The terrace reaches a maximum width of 12 miles (pl. 29) and ranges in elevation from about 350 feet above sea level near the ocean to 450 feet or more farthest inland, where it is limited by a high area of resistant igneous and metamorphic rocks. An excellent description of the terrace and its history has been given by Hertlein and Grant.[5]

On the terrace are a number of long narrow ridges, some of which rise nearly 100 feet above the general level of the terrace. The ridges are composed almost entirely of fine- to coarse-grained, arkosic sand of reddish or brownish color. The sand appears to have a maximum thickness of about 100 feet from the bevelled terrace surface to the top of the ridges. Between the ridges, the sand is generally absent, and in its place is a conglomerate about 20 feet thick, which is composed of metavolcanic gravels. This conglomerate is the Sweitzer formation.

The ridges have been ascribed to deposition by waves and wind at successive shorelines as the sea receded across the terrace. After complete withdrawal of the sea the ridges stood above the general level of the terrace in positions more or less parallel to the present shoreline. They now constitute obstacles to stream drainage, causing the local development of trellised stream patterns. Erosion has cut the ridges into short discontinuous segments that remain on the terrace between stream valleys. They are completely absent in the lowland area south of the city of San Diego, but reappear on the terrace near the Mexican border. The ridges occur discontinuously from the border northward to Oceanside, a distance of 40 miles, and they probably extend approximately 5 miles south of the border.

DESCRIPTION OF CONCRETIONS

Geographical Distribution

The ironstone concretions are restricted to the beach ridges, except where obvious local reworking has taken place. Accordingly, the map (pl. 29) shows the distribution of both concretions and beach ridges. In a few areas, such as the Mount Soledad and Point Loma regions, the presence of the beach ridges had not previously been reported and they were not noted until the concretions were mapped. The black areas of plate 29 are definite occurrences of concretions and beach ridges. The lightly cross-hatched areas indicate much-eroded beach ridges where there are few or no concretions, but as the character of the cemented sand now at the surface is similar to that underlying concretions elsewhere, concretions evidently were once present in abundance there.

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[5] Op. cit.

The soil in the areas of abundant concretions has been mapped as the Carlsbad loamy fine sand. The soil of the terrace flat between the beach ridges has mostly been mapped as the Redding sandy loam.[6]

Outcrops

In many areas the loose concretions are very abundant on the ground surface (pl. 32). In vertical sections of outcrops the concretions are abundant and loose from the surface downward to a depth of 2 or 3 feet. Below that depth they grade into a moderately well-cemented sandstone (pl. 31) in which some less well-defined concretions may be seen. In the field the concretions appear to comprise a larger bulk than the matrix. Near the surface the matrix contains much loose fine-grained sand and is dark gray owing to the presence of humus. At depth the matrix is a sandstone that is yellow to red, though not as red as the concretions. Because the top of this sandstone is ordinarily somewhat better cemented than the material above and below, it is referred to in the soil surveys as hardpan. Both the concretionary zone and the top of the sandstone are resistant to erosion and are removed chiefly by undermining of the softer sand below. Thus, the concretions form a caprock on steep slopes (pl. 31 *A*) that constitute the sides of ampitheater-like valleys.

The sandstone below the concretionary zone appears to contain no primary structures such as cross-bedding or horizontal layering. However, there are some old soil zones and also many vertical opaline cylinders and tubes that have formed around plant roots. Similar opalized root-tubes are common in caliche deposits of the region.[7]

Shape

Practically all of the concretions are nearly spherical in shape. Only a few flattish ones were found, and these are exceptional. The spherical shape is reflected in the presence of internal growth bands which are roughly concentric and represent zones of denser cementation by iron oxide (pl. 33).

Grain Size

Mechanical analyses were made of samples collected from the surface to depths as great as 200 inches in cliffs or road cuts through the beach ridges at each of the three localities indicated on plate 29. The grain-size histograms for many of the samples have two maxima, one for the concretions and one for the sand matrix (fig. 1). The sand portion, or matrix, is similar in grain size and sorting from top to bottom of the section. Grain-size data for the sand matrix from each locality are sumarized in table 1.

In all three localities the concretions are most abundant from the surface to a depth of about 3 feet. Below that depth the sand contains some lumps that are somewhat better cemented and redder than the matrix.

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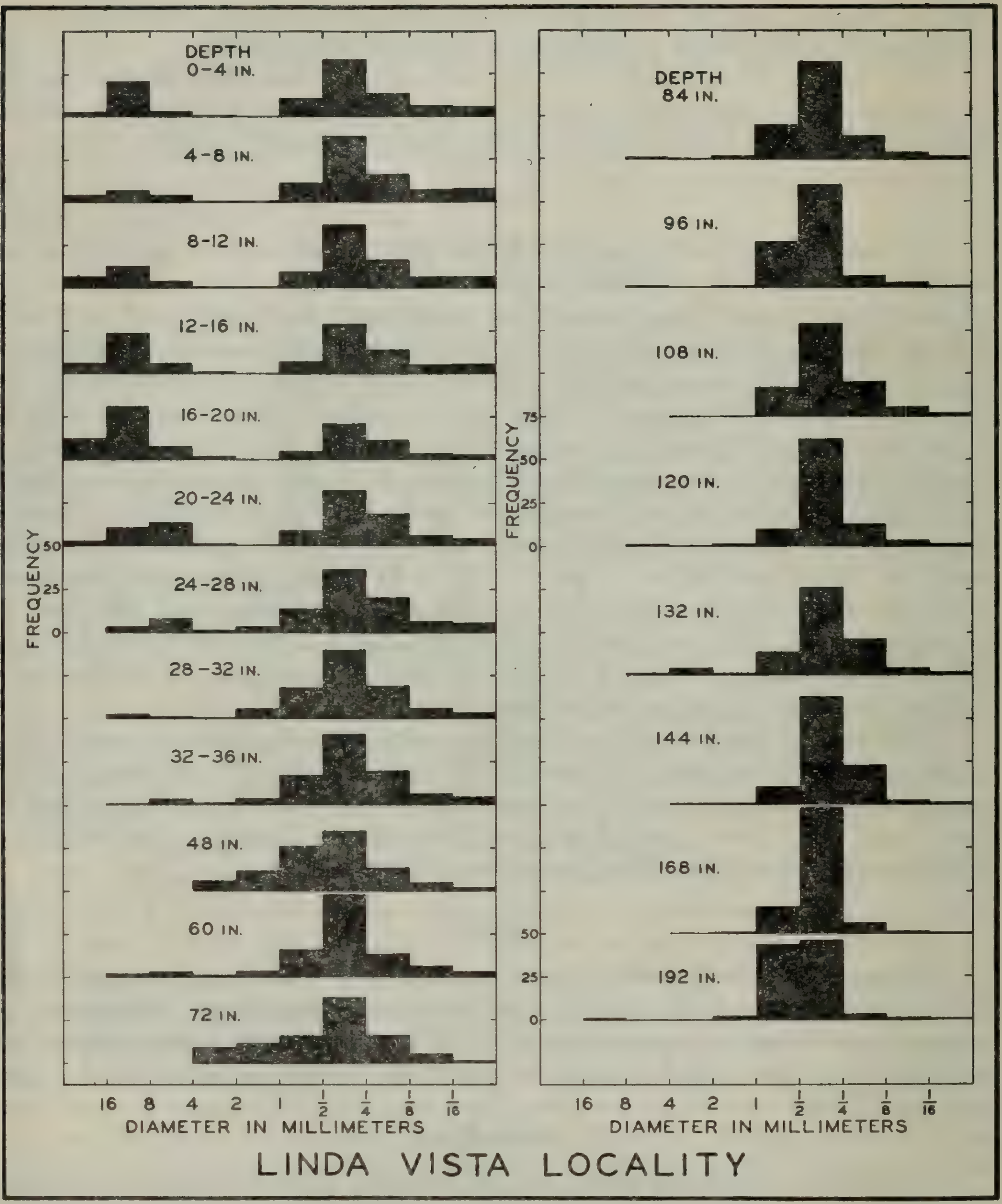
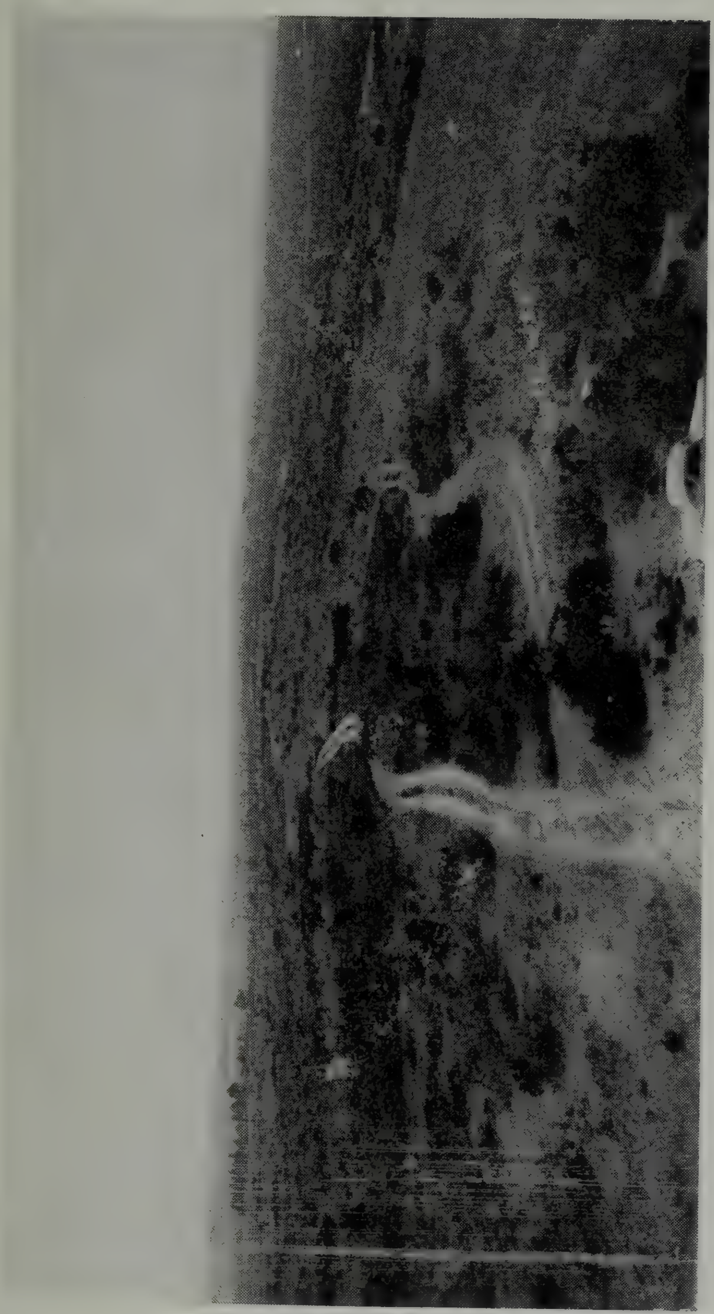
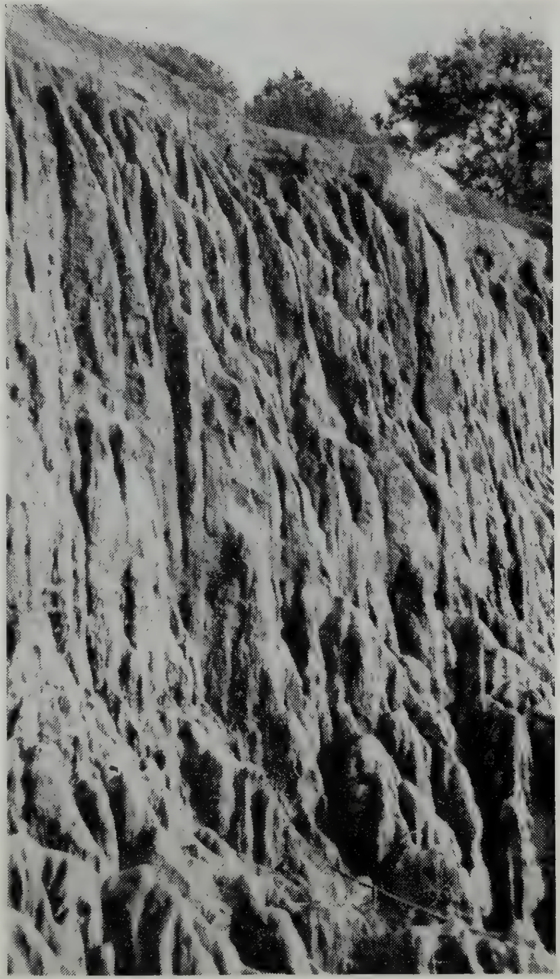


FIG. 1. Variation with depth of grain-size of concretions and sand matrix.



LARGE BEACH RIDGE

As viewed from water tower about 6 miles north of San Diego, California.



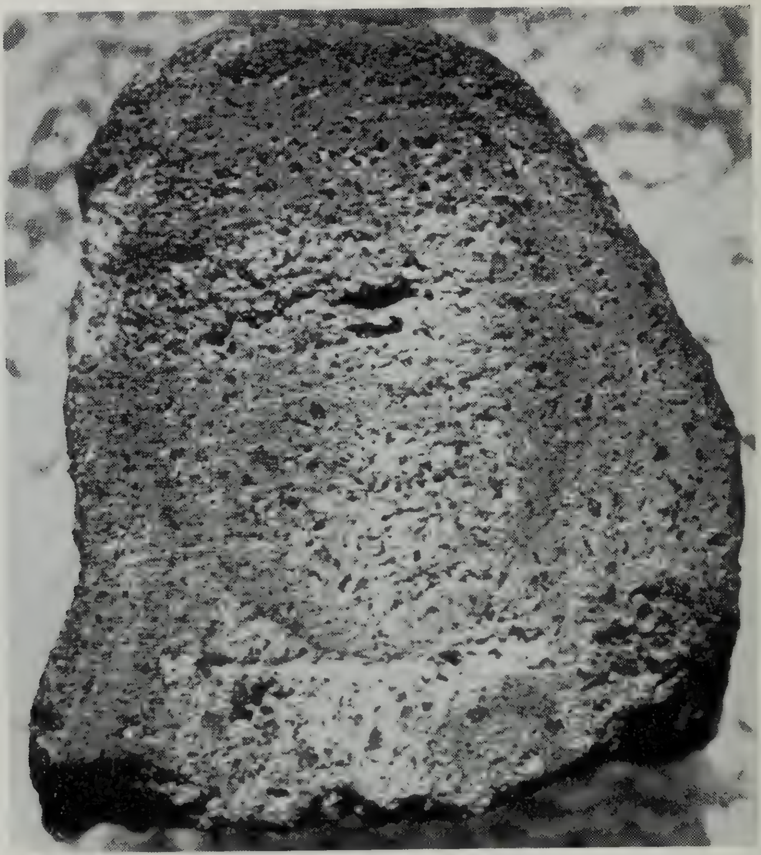
A, CONCRETIONARY LAYER

Capping easily eroded sandstone near Theosophical Institute, Point Loma locality, San Diego County.

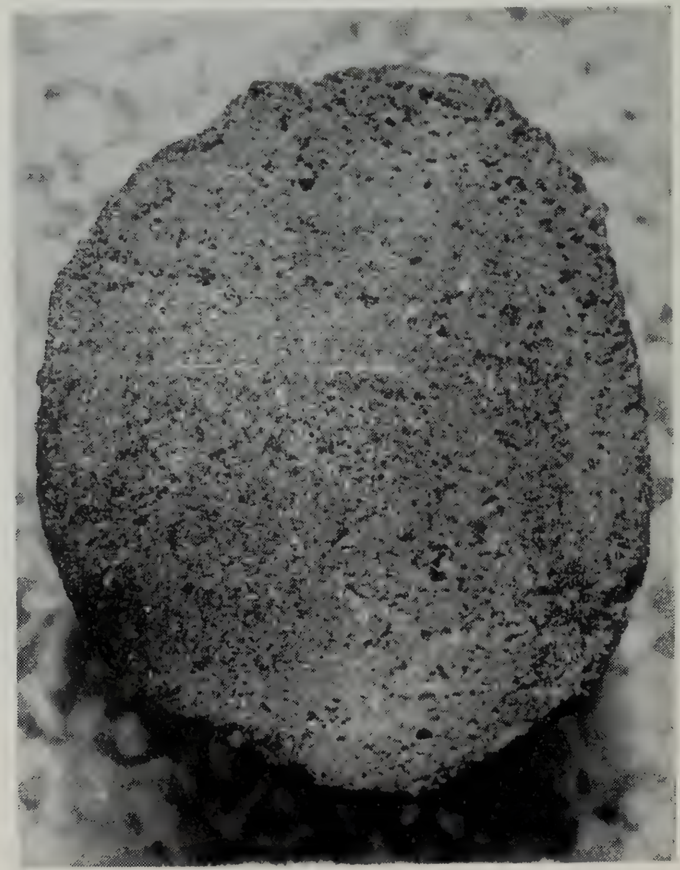
B, CONCRETIONARY LAYER

In beach ridge near village of Linda Vista, Linda Vista locality, San Diego County.

CONCRETIONARY SURFACE
Mount Soledad locality, San Diego County.



A, CROSS-SECTION OF CONCRETION SHOWING CONCENTRIC STRUCTURE



B, CROSS-SECTION OF CONCRETION SHOWING CONCENTRIC STRUCTURE

Table 1. Grain size of sand matrix.

	Linda Vista	Mount Soledad	Point Loma
Number of analyses	20	12	15
Median diameters (mm.)	0.285-0.490	0.270-0.445	0.222-0.322
Average	0.338	0.335	0.273
Sorting coefficients	1.17-1.57	1.24-1.59	1.57-1.80
Average	1.42	1.45	1.65

These lumps are very irregular in outline, not smooth like the well-defined concretions nearer the surface. Because the lumps are only slightly harder than their matrix they could not be separated in all cases without being crushed, so their percentage abundance given on the histograms is not very reliable. It seems reasonable that most of them represent the formative stage of concretions. A few are cylindrical, consisting of partly opalized root tubes, but, as this characteristic does not occur in the shallower more typical concretions, it is not considered a required stage in concretion formation. As shown by the histograms for the Linda Vista locality, the concretions range in size from about 2 to 16 millimeters, and average about 9 millimeters. Rarely, even larger ones having diameters up to 30 millimeters were found.

Composition

Sand. The concretions and their matrix are non-calcareous and unfossiliferous. Blocks from the Sweitzer formation carry on their surface many clusters, about half a millimeter in diameter, composed of tiny gypsum crystals.

Sand accompanying the ironstone concretions is covered by a red film of iron oxide. After the film was removed by boiling in dilute hydrochloric acid and stannous chloride, the sand was found to be angular to sub-angular. Only a few of the larger grains are as highly rounded and frosted as those generally considered characteristic of wind action. The small diameter of most of the sand grains would not be conducive to rounding and frosting. For example, in the dunes at El Segundo the grains that are of equally small size are also angular, and only the larger ones are rounded and frosted.

The heavy mineral composition of cleaned sand from a depth of 8 to 12 inches at the Mount Soledad locality and the Linda Vista locality is given in table 2. Samples from deeper than 7 or 8 feet in the beach

Table 2. Composition of heavy minerals of sand.

	Mount Soledad matrix 12″ to 16″	Linda Vista matrix 8″ to 12″	Linda Vista concretions 8″ to 12″
Hornblende	56%	9%	10%
Epidote	15	7	7
Magnetite	13	76	71
Leucoxene	4	1	5
Zircon	3	1	2
Biotite	3	1	0
Ilmenite	2	1	0
Garnet	2	3	3
Glaucophane	2	0	0
Sphene	0	1	2
	100%	100%	100%

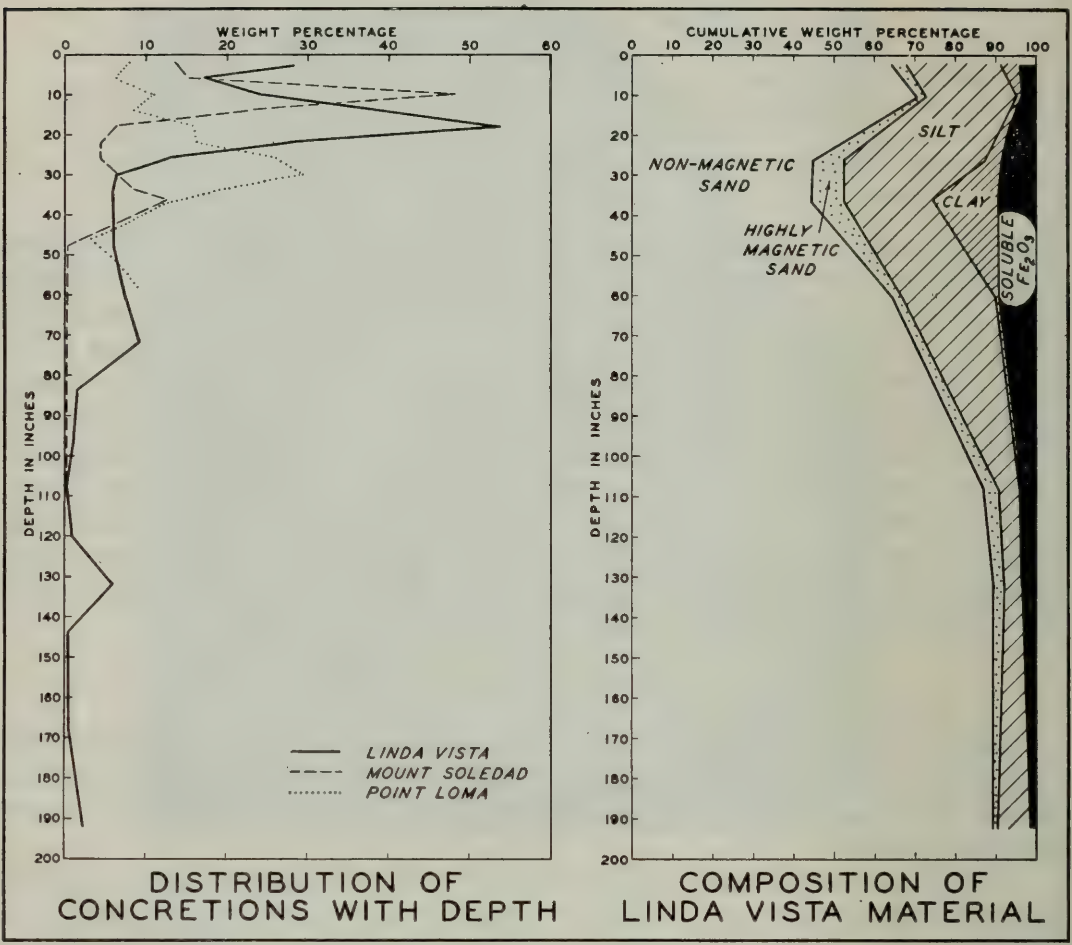


FIG. 2. Depth distribution of concretions, non-magnetic sand, magnetic sand, silt, clay, and soluble iron oxide.

ridges also contain a few pieces of opal derived from root tubes. It is apparent that the heavy minerals of the matrix and from within the concretions are similar, indicating that the iron oxide merely enclosed the sand in place. At Linda Vista the flood heavy mineral is magnetite, which consists almost entirely of well-rounded grains. At the Mount Soledad locality the flood heavy mineral is hornblende—probably derived in part from a different source, most likely Mount Soledad, which was an island when the sea covered the terrace. Sand matrix at Point Loma is finer grained than that of either of the other two localities, possibly because of the greater distance of transportation from that source area.

The light fraction of the sand matrix from several depths at the Linda Vista locality was studied by a staining technique. The results shown in table 3 indicate that feldspar is sufficiently abundant, especially at depth, to warrant description as arkosic sand. Near the surface feldspar is less abundant, perhaps because of more complete weathering of the sand.

Table 3. Composition of light minerals of sand matrix from the Linda Vista locality.

	Depth in inches		
	0 to 4	8 to 12	192
Quartz	74%	72%	61%
Orthoclase	8	16	4
Plagioclase	18	12	35
	100%	100%	100%

Iron Oxide. The percentage of iron oxide in coarsely crushed samples was determined as weight loss after treatment with boiling dilute hydrochloric acid and stannous chloride. A titration method for iron proved impractical because of the color-masking effect of silt and clay. Whole samples from various depths in the Linda Vista locality ranged between 1.8 percent Fe_2O_3 at the greatest depth to over 9 percent between depths of 30 to 90 inches. Values of only 4 percent were found near the ground surface. Several concretions from a depth of 8 to 12 inches were brushed free of clinging sand and also tested. They contained 15 percent Fe_2O_3, a much higher percentage than any of the other samples that consisted of both concretions and sand matrix. It is notable, however, that the depth distribution of Fe_2O_3 does not correspond closely to that of concretions (fig. 2), but, instead, it covers a broader depth zone that extends well below the depth of abundant concretions.

Insoluble Residue. The residue left from the iron determination was noted to have a high content of silt (0.062 to 0.004 mm.) and clay ($<$0.004 mm.). Mechanical analyses showed that these finer constituents were most abundant at depths between 24 and 36 inches, where together they constitute 38 to 39 percent of the sediment. Below 100 inches they amount to less than 5 percent. Several cleaned concretions that were analyzed alone contained 47 percent silt and clay, a signficantly higher proportion. Examination of figure 2 reveals that the silt and clay, like the iron oxide, is most abundant below the depth of most abundant concretions.

CONCLUSIONS

The beach ridges pose an interesting problem. At least two alternative origins must be considered: beaches formed by ocean waves and currents, and transverse dunes formed of sand blown from beaches. In favor of the aqueous origin is the general parallelism of the ridges with the present coast; against it is the fact that the ridges are fairly steep on both sides—unlike beaches or bars—and also the fact that there is no remnant whatever of lagoonal sediments behind them. Against the eolian origin is the general absence of rounding and frosting of the sand grains and lack of cross-bedding; in its favor are the facts that the grains are so small that rounding and frosting may not be possible especially if only a short distance of eolian transportation were involved, that the excellent sorting of the sand is more like that of dunes than of most beaches, that root tubes occur in the deeper parts of the ridges and appear, therefore, to mark the positions of plants around which the sand may have been blown. The writer has concluded that the eolian origin of the beach ridges is the more probable. In their areal extent and general composition they are somewhat similar to Pleistocene dune sands along Santa Monica Bay[8] although the latter contain no ironstone concretions. Other similar beach or dune ridges have been described by Johnson.[9]

Several possible methods of concretion formation are worthy of consideration. It is apparent that the concretions were not formed elsewhere, and then transported to the beach ridges, because of the even thickness of the surface concretionary layer, the presence of formative stages in the underlying sandstone, and the similarity of sand within and without the concretions. If formed in place, the concretions could result from concentration of iron carried by water and deposited about numerous nuclei. The high and non-directional permeability of the sand allowed the concretions to grow with nearly spherical shapes. As the concretions never occur in place on the slopes of valleys cut through the ridges it is apparent that the period of concretion formation closely followed the deposition of the sand and then ceased before dissection of the ridges took place. The abundant silt and clay within the concretions indicates that cementation took place only after some weathering of the sand had occurred.

It is suggested that weathering of the surface layers of sand produced silt and clay that was carried downward through the pores of the sand by vadose water. Because of the height of the beach ridges above the surrounding surface the water table must always have been so deep that rain-water rarely reached it, but instead remained as pellicular, or skin, water until it evaporated. The silt and clay would then have been deposited above the lower limit reached by the pellicular water. Presumably, iron was also carried in solution and deposited with the silt and clay. Eventually, the continued deposition of silt and clay in this zone of illuviation formed a hard-pan having such a low permeability that it blocked further passage of vadose water. At the present, rain-water stands in puddles for some time on the Carlsbad loam. Perhaps the quiet stand of the vadose water atop the hard-pan favored a concentration of the iron in concretionary form rather than a dissemination with the silt and clay over a wide range of depth. Such an origin would explain the prevalence of concretions above the hard-pan zone of abundant silt and clay. Continuous weathering and removal of the weathering products by vadose water and run-off has since lowered the ground surface and permitted a thin residual concentration of the concretions at the very surface (pl. 32). As the sand that served as a source of silt, clay, and iron, as well as a matrix, is absent in the inter-beach ridge areas, no concretions were formed there.

In its structure and composition the concretionary zone is very similar to pisolitic laterite described by Pendleton[10] and others. However, most authors believe that laterites are formed by residual concentration of sesquioxides or by their transportation in ground water from underlying iron-rich rocks. Neither explanation seems to fit the observed relationships as well as the one proposed above.

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ECONOMIC VALUE

The thinness of the layer of concretions and its low iron content as compared with present commercial iron ores eliminate any possibility of its being exploited profitably for iron. However, laboratory tests showed that the concretions possess a magnetism sufficiently high that they might affect magnetometer surveys which are made in the vicinity of the beach ridges. In fact, if a magnetometer survey of the Linda Vista terrace in San Diego County were to be made, the magnetic highs would probably mark the positions of beach ridges as accurately as would a map of the distribution of the concretions.

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GEOLOGY OF THE RED MOUNTAIN MAGNESITE DISTRICT, SANTA CLARA AND STANISLAUS COUNTIES, CALIFORNIA*

By Alfred J. Bodenlos**

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** Geologist, U. S. Geological Survey.

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ABSTRACT

The Red Mountain magnesite district is on the border of Santa Clara and Stanislaus Counties, California, 31 miles by road south of Livermore, and 28 miles by road west of Patterson. The magnesite deposits were mined from 1905 to 1945, and the total recovery has been in excess of 870,000 short tons. Reserves remaining in the deposits in 1944 were 82,600 tons measured, 47,900 tons indicated, and 48,700 tons inferred, a total of 179, 200 short tons.

The magnesite deposits are in an ultramafic intrusive body underlying Red Mountain. The ultramafic body, probably a sill, is a complex consisting of peridotite, dunite, pyroxenite, and gabbro, and is intrusive into the Franciscan formation of Upper Jurassic (?) age. The dunite has been almost completely serpentinized, but the other rocks of the intrusive complex are essentially unaltered, except along shear zones which were probably formed during regional orogeny. These shear zones are serpentinized and are the sites of the magnesite deposits.

The mineralization products are magnesite, dolomite, manganese oxide, chalcedony, opal, deweylite, sepiolite, and calcite, deposited in that order. The magnesite is cryptocrystalline, has conchoidal fracture, and resembles unglazed porcelain. Most of it is white, but it may be gray, light green, or pink owing to included material. It occurs as nodular aggregates replacing serpentine and as fissure-filling in irregular fractures, breccia zones, and open shears. Massive lenses of magnesite result through coalescence of smaller nodules. Minor amounts of dolomite and manganese oxide are included in the magnesite. Silica minerals, hydrated magnesium silicate minerals, and calcite are found in larger amounts as fracture fillings. Small movements occurred repeatedly in the shear zones during the mineralization, fracturing previously deposited material and providing open fissures for deposition of subsequent minerals. Recent deposits of calcareous sinter occur in the beds of streams issuing from the area underlain by the igneous rock.

Magnesite deposition was closely controlled by shear-zone structure. Although shear zones are numerous through the peridotite, only certain closely associated groups of zones contain magnesite veins. Within individual shear zones, the wide parts of the magnesite veins are clearly related to irregularities of their containing shear zones. Massive high-grade lenses of magnesite are localized by the shear-plane pattern within the shear zones. The structures therefore govern the size and shape, and to some extent the grade, of the magnesite bodies. Minable bodies range in length from 100 to 900 feet, are as much as 35 feet in width, and have a vertical range from 50 to 660 feet. The grade of mined material is high, averaging from 94 to 95 percent magnesite, the remainder being mostly included serpentine and dolomite.

Correlation of mineralogic, structural, and geochemical data indicates that the deposits were derived from hypogene and probably epithermal solutions. Hot waters charged with carbon dioxide under high pressure reacted with serpentine at depth, taking magnesium and silicon into solution. Magnesite was deposited as the carbon dioxide pressure lessened when the solutions approached the surface. Silica was deposited next, then hydrated magnesium silicates. The solutions probably were cooler when calcite was deposited. The deposition of these minerals probably occurred in the Tertiary period.

INTRODUCTION

Magnesite, the carbonate of magnesium, is commercially important as a source of magnesia for refractories and magnesium oxychloride cement, and also as an ore of magnesium metal. Magnesite has a world-wide distribution [1] and occurs either as an obviously crystalline or marblelike material or as a dense, cryptocrystalline aggregate resembling unglazed porcelain. Crystalline magnesite occurs in many associations such as: (1) massive replacement deposits in dolomite;[2] (2) disseminated grains in the contact aureoles of ultramafic intrusive rocks;[3] (3) veins in schists and ultramafic rocks;[4] (4) disseminated grains as a primary constituent of ultramafic rocks;[5] and (5) crystals in vugs in melaphyre, a black dike rock.[6] In addition, A. F. Rogers [7] describes euhedral magnesite in cinnabar veins near San Jose, California, and isolated euhedral crystals have been found in some dolomitic limestones.[8] Cryptocrystalline magnesite is found as nodules and veins in ultramafic rocks,[9] in dolomite or dolomitzed limestone,[10] and in altered tuff.[11] Cryptocrystalline magnesite also occurs as sedimentary beds, in places of considerable thickness and extent,[12] and as a minor constituent of anhydrite beds.[13]

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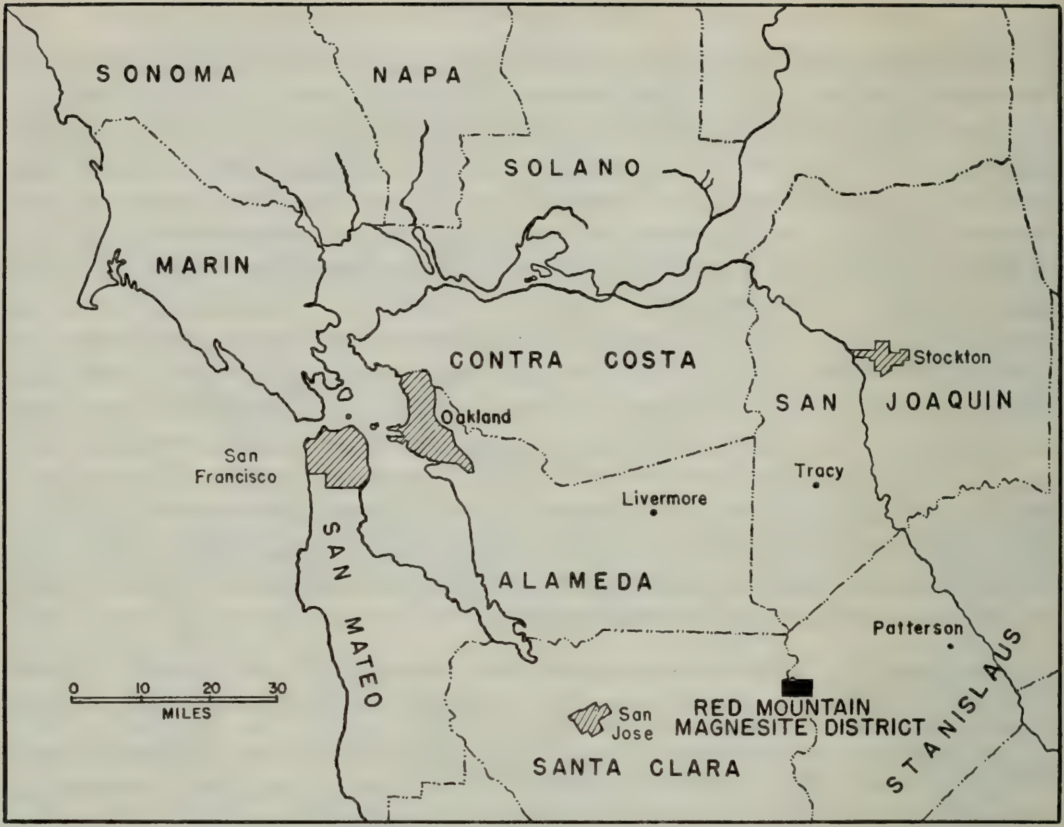
SONOMA
NAPA
SOLANO
MARIN
CONTRA COSTA
Oakland
San Francisco
SAN JOAQUIN
Stockton
Tracy
Livermore
SAN MATEO
ALAMEDA
Patterson
STANISLAUS
0 10 20 30
MILES
San Jose
RED MOUNTAIN MAGNESITE DISTRICT
SANTA CLARA

FIGURE 1. Index map of central California showing location of Red Mountain magnesite district

Of all these types of deposits, the largest and most important commercially are the massive crystalline replacement deposits in dolomite, although the cryptocrystalline nodular and vein deposits in ultramafic rocks have yielded large tonnages of magnesite. The sedimentary beds in southern Nevada and southeastern California contain large amounts of magnesite, but as yet have not been utilized.

The magnesite deposits at Red Mountain, in common with most other magnesite deposits in the Coast Ranges and foothill belt of the Sierra Nevada in California, consist of cryptocrystalline nodules and veins in ultramafic rocks. The deposits of California, particularly those at Red Mountain and Porterville, yielded nearly all the magnesite produced in the United States until 1916 when the massive crystalline replacement deposits at Chewelah, Washington, came into production.[14] The Red Mountain district continued to produce nearly every year to 1945, but the proportion of the national total has been small. Economic factors, as well as depletion of reserves, caused a decline in the production from the cryptocrystalline deposits, with the result that during the second World War the deposits at Red Mountain were the only ones being mined. The major sources of magnesia during this war were crystalline magnesite, sea water,[15] dolomite, and brucite. Despite higher mining costs at Red Mountain as compared with open-pit quarrying, the high grade of the magnesite made it more desirable for special uses. Production at Red Mountain ended, however, toward the end of the war when the demand for magnesia lessened.

Location and Accessibility. The Red Mountain district is on the border of Santa Clara and Stanislaus Counties, California, in secs. 17, 18, 19, and 20, T. 6 S., R. 5 E., and secs. 13 and 14, T. 6 S., R. 4 E., Mount Diablo Base and Meridian (see fig. 1 and pl. 38). The district is 31 miles by winding road southeast of Livermore, the shipping point on the Western Pacific Railroad, and 24 miles by road west of Patterson on the Southern Pacific Railroad.

The five magnesite deposits in the district occupy a triangular area 9,500 feet long and 5,500 feet wide at the eastern end. All deposits are either in sec. 18, T. 6 S., R. 5 E., or immediately adjacent thereto. The Western mine, the only active operation in the district in 1944, consists of workings on the two largest vein groups. The Westvaco Chlorine Products Corporation leases all of the Western mine claims (pl. 39) on a royalty basis from the several owners. The Red Mountain mine, also known as the Patterson mine, is owned by T. L. James, and in 1942 was under lease to Jos. Biallis and H. R. Vail[16]; this mine has been inactive since June 1942. The two small deposits in the northwestern part of the district are leased to the Westvaco Chlorine Products Corporation, and also are inactive.

Surface Features at Red Mountain. The deposits are on the flanks of Red Mountain, the highest point in this part of the Diablo Range. Red Mountain is a northwest-trending ridge and is the divide between drainage to the southwest and west and drainage to the northeast and east. The northeast side of the ridge is drained by the headwaters of Puerto

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[14] Stone, R. W., Magnesite deposits of Washington: Eng. and Min. Jour., vol. 105, pp. 665-668, 1918.

[15] Seaton, M. Y., Production and properties of commercial magnesias: Am. Inst. Min. Met. Eng. Trans., vol. 148, pp. 11-31, 1942.

[16] Red Mountain magnesite mine, Stanislaus County, California: U. S. Bur. Mines War Minerals Rept. 105, 1943.

Creek (see pl. 38), which enters the San Joaquin Valley near Patterson. Sweetwater and Beauregard Creeks drain the southwest side of the ridge and reach Livermore Valley in the Arroyo del Valle. Farther north, the southwest side of the ridge is drained by the Arroyo Mocho, along which the mine road from Livermore was made into the mountains. These features may be seen on the Tesla, Mt. Hamilton, and Mt. Boardman topographic quadrangle maps. U. S. Agricultural Adjustment Administration aerial photographs Nos. CIV-R 350-33 and -34, and CIV-R 352-18 and -19 include the magnesite district.

The highest point on Red Mountain is 3,670 feet above sea level, 1,500 feet above the broad San Antonio Valley to the southwest, and about 1,900 feet above the narrow valleys of the Puerto drainage system to the northeast. The flanks of the ridge are steep, especially on the northeastern side, and are covered with a rather heavy growth of chaparral. In the vicinity of the deposits exposures of bedrock usually are small and scattered.

Springs are numerous on the lower flanks of the ridge. A perennial spring issuing from a gully east of the Western mine camp furnishes sufficient water for camp, mill, and mine requirements except in unusually dry years. The Red Mountain Mine has a heavy flow of water from the lower tunnel but this would be unfit for camp use. In the past, water was pumped over a spur from a spring in the next gully to the north.[17] Intermittent streams flow below the two northwestern deposits but wells would have to be drilled to insure perennial supply for operations.

Four of the five magnesite deposits are on the western slope of Red Mountain. The White Diamond-Silver vein group (see pl. 38, locality 1) and the White Queen vein group (locality 2), comprising the Western mine, are on the upper slopes of the gulch of a small west-flowing tributary of Sweetwater Creek, and their workings range from an altitude of 2,900 feet to 3,540 feet. The calcining plant of the Western mine is in this gulch at an altitude of 2,550 feet, 490 feet below the White Diamond tramhead and 630 feet below the tramhead of the White Queen veins. The Fidelity and Security deposits (localities 5 and 6) are on the slopes of other west-flowing tributaries of Sweetwater Creek, and are less than a mile northwest of the White Diamond-Silver vein group. The Red Mountain mine (locality 4) is on the northeast side of Red Mountain. Its workings are in the drainage area of Hideout Creek, and extend from an altitude of 2,200 feet to 2,560 feet.

History and Production. Development work was started at the Western mine in 1899 and the first shipments were made in 1905.[18] With the exception of a temporary shutdown in 1935-36, the mine was in continuous operation from 1905-45. Prior to the first World War, production was hampered by conflicting interests among the owners, but in 1919, legal difficulties were settled and the property was leased to C. S. Maltby. Maltby and C. S. Maltby Company, Ltd., held the lease until November 1931, when it was purchased by the California Chemical Corporation. In 1937, the Westvaco Chlorine Products Corporation purchased the California Chemical Corporation and the lease, and has operated the Western mine since that time.

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[17] U. S. Bureau of Mines, op. cit., p. 4.

[18] Hess, F. L., op. cit., p. 34. Seaton, M. Y., op. cit., pp. 13-14.

Table 1. Production of magnesite, Western mine, from 1917-32, inclusive.[1]

Year	Production (short tons)	Year	Production (short tons)
1917	5,733	1925	37,125
1918	5,500	1926	28,000
1919	9,640	1927	27,134
1920	25,612	1928	21,843
1921	25,000	1929	26,646
1922	30,000	1930	26,138
1923	36,244	1931	12,498
1924	33,750	1932	2,641

[1] Courtesy of California State Division of Mines, by permission of Olaf P. Jenkins, State Mineralogist, and the Westvaco Chlorine Products Corporation.

Total recovery at the Western mine from 1905-45 has been approximately 870,000 tons. Production figures from 1917-32 are given in table 1.

The Red Mountain mine was discovered in 1915 and has been operated intermittently since then, producing 50,000 tons prior to 1925,[19] and about 20,000 tons from 1926 to 1941.[20] Among the lessees since 1922 were: California Magnesite Company (1922-32), California Chemical Corporation (1935-37), Biallis and Hoff (1941-42), and Biallis and Vail (1942-43). But for a small tonnage recovered in 1941, the mine has been inactive since 1936.

Several thousand tons were mined from the Security deposit during the first World War, but the mine has been closed since. The Fidelity deposit has never been operated.

In 1944, the Westvaco Chlorine Products Corporation mined the magnesite by cut-and-fill stoping, thus assuring maximum recovery in veins with exceedingly variable widths. Broken ore was hand-sorted in the stopes. The fines, containing most of the silicon-bearing minerals, were screened from the magnesite before it was transported via aerial tram to the kilns. At the kilns, the high-grade material was sorted by hand from the lower-grade magnesite and was stock-piled awaiting shipment as crude ore. The remainder was crushed to pass through $\frac{1}{2}$-inch mesh screens and burned in rotary kilns at a temperature of 1,500° C., to produce "dead-burned magnesite" for manufacture of refractory brick. A more detailed account of operations is given by Perry and Kirwan[21]; since publication of the article, a second rotary kiln was added to the plant. Most of the crude magnesite was processed into insulating material, and a few tons of the purest magnesite was used in the chemical industry.

Prior to management by the Westvaco Chlorine Products Corporation, the magnesite was mined by shrinkage stoping and burned in stack kilns, as described by L. A. Palmer.[22] A considerable part of the magnesite was "caustic-calcined," or burned at lower temperatures, to yield a chemically reactive magnesia.

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[19] Bradley, W. W., op. cit., p. 98.

[20] Courtesy California State Division of Mines.

[21] Perry, J. B., and Kirwan, G. M., The Bald Eagle magnesite mine, California: Am. Inst. Min. Met. Eng. Trans., vol. 148, pp. 35-36, 1942.

[22] Palmer, L. A., Magnesite mining in California: Am. Inst. Min. Met. Eng. Trans., vol. 75, pp. 750-755, 1927.

Field Work and Acknowledgments. Study of the Red Mountain district started in June 1943, when Eugene Callaghan and the writer spent several days mapping underground workings. In the period from September 1943 to April 1944, the district was mapped by the writer, with the very able assistance of James V. Barnes and Fred H. Howell. The project was under the direction of Mr. Callaghan. The writer is indebted to him for many suggestions and fruitful discussions throughout the field study and subsequent laboratory and library research. The manuscript was greatly improved by the critical readings of F. G. Wells, G. T. Faust, Michael Fleisher, and C. J. Vitaliano, all of the U. S. Geological Survey.

In the immediate vicinity of the Western mine, the surface was mapped on a scale of 50 feet to the inch, peripheral areas on a scale of 200 feet to the inch. Underground workings were mapped on a scale of 50 feet to the inch. In the mapping of the surface of the Red Mountain mine, the scale used was 200 feet to the inch, and for underground workings the scale used was 40 feet to the inch. Mapping was greatly facilitated by the use of surface survey stations and underground maps of the Western mine and underground maps of the Red Mountain mine, furnished through the courtesy of the Westvaco Chlorine Products Corporation. The regional map was compiled from mapping on U. S. Agricultural Adjustment Administration aerial photographs.

The writer thanks the officials of the Westvaco Chlorine Products Corporation, who placed all facilities and pertinent records at the disposal of the Geological Survey party, particularly Mr. W. K. Wallace, vice president in charge of western operations of the company, Mr. J. B. Perry, manager of mines, Mr. G. M. Gaylord, superintendent of the Western mine, Mr. Phil Cayot, mine foreman, and Mr. R. F. Love, engineer.

Previous Geologic Work. Early studies of the geology in the Red Mountain district were made by F. L. Hess [23] and H. S. Gale.[24] W. W. Bradley [25] briefly described the geology, mining, and calcining operations. L. A. Palmer [26] includes a short account of the geology of the Western mine in his paper on magnesite mining in California. The U. S. Bureau of Mines [27] published a report on the Red Mountain mine. The rocks of the ultramafic intrusive body at Red Mountain have been described by H. E. Hawkes Jr., F. G. Wells, and D. P. Wheeler Jr.,[28] in connection with the study of the nearby chromite and quicksilver deposits. N. L. Taliaferro [29] wrote an extensive paper on the Franciscan formation, the principal sedimentary rock in this area.

GEOLOGY

General Features

The Red Mountain area is underlain by the Franciscan formation, of Upper Jurassic (?) age, and by ultramafic rocks intrusive into the sedimentary strata. The ultramafic intrusive body consists mainly of peridotite and dunite, but contains some gabbro and pyroxenite. The intrusive body is in fault contact with the closely folded Franciscan formation. The dunite has been almost completely serpentinized, but the peridotite has been serpentinized only along fractures and in shear zones. These serpentinized shear zones in the peridotite contain the major magnesite deposits.

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[23] Op. cit.
[24] Op. cit.
[25] Op. cit.
[26] Op. cit.
[27] Op. cit.
[28] Hawkes, H. E. Jr., Wells, F. G., and Wheeler, D. P. Jr., Chromite and quicksilver deposits of the Del Puerto area, Stanislaus County, California: U. S. Geol. Survey Bull. 936-D, pp. 79-110, 1942.
[29] Taliaferro, N. L., Franciscan-Knoxville problem: Am. Assoc. Petroleum Geologists Bull., vol. 27, pp. 109-219, 1943.

Sedimentary Rocks

The sedimentary strata comprising the Franciscan formation occur both north and south of the rocks of the ultramafic intrusive body that underlies Red Mountain (see pl. 38). The area underlain by the Franciscan formation forms low gentle hills, contrasting with the greater relief and dissection in the area underlain by the ultramafic rocks.

The rocks of the Franciscan formation consist of dark-gray shale, red shale, green sandstone, brownish arkose, thin-bedded red chert, and light-green chert, together with extrusive basalts. Small amounts of intrusive granodioritic gneisses also are in this formation. All lithologic types are abundantly veined by ''bull'' quartz and in a few places by calcite. This assemblage is typical of the Franciscan formation as described by N. L. Taliaferro.[30] Some shale is slightly metamorphosed to the phyllite stage, and some schist is reported along parts of the intrusive contact.[31] On the whole, the sedimentary rocks are little altered, except for the weathering of unstable constituents in the arkose.

In the area studied by the writer, the sedimentary rocks are strongly folded. The rocks strike roughly parallel to the intrusive contact and dip steeply, either toward or away from the intrusive body. Close to the south contact with the intrusive body, exposures show steeply dipping strata, complexly and tightly drag-folded. Detailed study of the structure is limited by lack of sufficient outcrops in the Franciscan terrane.

Taliaferro [32] considers the Franciscan formation as representing a comparatively short time interval, occupying part of the Tithonian and possibly including some upper Kimmeridgian of Upper Jurassic age.

Ultramafic Intrusive Body of Red Mountain

The intrusive body of Red Mountain has not been mapped in its entirety but is known to be an elongated tabular mass that bellies and pinches along its major dimension and tapers at both ends. It is at least 9 miles long, extending 6 miles east and at least 3 miles northwest of the Western mine camp in sec. 18, T. 6 S., R. 5 E. About 1 mile east of the Western mine the outcrop of the intrusive body is 8,500 feet wide, but it narrows abruptly at the east sideline of sec. 17, T. 6 W., R. 5 E., to 3,000 feet (see pl. 38). In the area containing the magnesite deposits, the intrusive averages 6,500 feet in width; it narrows gradually to the northwest beyond the magnesite area.

The mass trends west to northwest, roughly parallel to the strike of the sedimentary rocks. The contact between the intrusive and the sediments everywhere is covered. Close to this contact the peridotite has been sheared and serpentinized, and the Franciscan sedimentary rocks are closely drag-folded. These features strongly suggest faulting at the contact within the mapped area, although the evidence is not as conclusive as at the eastern end of the mass, where H. E. Hawkes Jr. and others[33] found both the Franciscan formation and rocks of Cretaceous age in fault contact with the intrusive. Where the contact shows distinctly on aerial photographs, it is quite straight, and inasmuch as the relief of the region is several hundred feet, the contact must be steep. Because faulting has obscured the primary intrusive relationships, the structure of the intrusive mass can be determined only from indirect evidence. The intrusive body is probably a sill or laccolith because its longest dimension is roughly parallel to the strike of the sedimentary rocks. A. S. Huey[34] has mapped as a sill a nearby intrusive mass with similar composition.

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[30] Op. cit., pp. 130-150.
[31] Hawkes, H. E. Jr., and others, op. cit., p. 85.
[32] Op. cit, pp. 194-195.

According to H. E. Hawkes Jr.[35], the intrusive is a complex consisting of peridotite, dunite, gabbro, and pyroxenite. In the magnesite area, the intrusive is predominantly peridotite, but contains small bodies of dunite and a few veins and pods of pyroxenite. Most dunite bodies are in the central part of the intrusive body, with longest dimensions approximately parallel to the length of the entire complex. This is comparable to the position of dunite at the eastern end of the intrusive body as mapped by Hawkes. Pods of pyroxenite up to several feet in length are most frequent near peridotite-dunite contacts. This petrographic assemblage is comparable to that of many other ultramafic intrusives, which consist mainly of peridotite and contain only minor pyroxene-free bodies.[36]

H. E. Hawkes Jr.[37] states that the age of the intrusive body at Red Mountain is unknown from field evidence in the adjacent Del Puerto area, but states the possibility that similar rocks elsewhere are post-Franciscan and pre-Chico (Cretaceous).

N. L. Taliaferro[38] notes that most ultramafic intrusive bodies in the California Coast Ranges are sill-like, essentially concordant, and were intruded prior to deformation of the sedimentary rocks. He concludes that most of the intrusions occurred either in late Franciscan or early Knoxville time, and that all were intruded prior to the Paskenta stage of the early Cretaceous.

Petrology

Peridotite. Peridotite is an ultramafic rock consisting chiefly of olivine and pyroxene. Most of it contains secondary serpentine and magnetite. Fresh peridotite at Red Mountain is a crystalline, gray-green to brown-green rock. The relative proportions of olivine and enstatite vary, but olivine always predominates and usually forms at least 75 percent of the rock. Enstatite-free rock locally forms small dunite areas in the peridotite. Rude banding of enstatite grains is found in a few places but no widespread development of tabular or linear structure was seen.

The average length of both olivine and enstatite grains is from 2 to 3 millimeters, but may range from 1 millimeter to 5 millimeters. Most chromite grains are about 1 millimeter in diameter. Under the microscope, both olivine and enstatite appear as subhedral grains; some olivine

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[33] Op. cit.

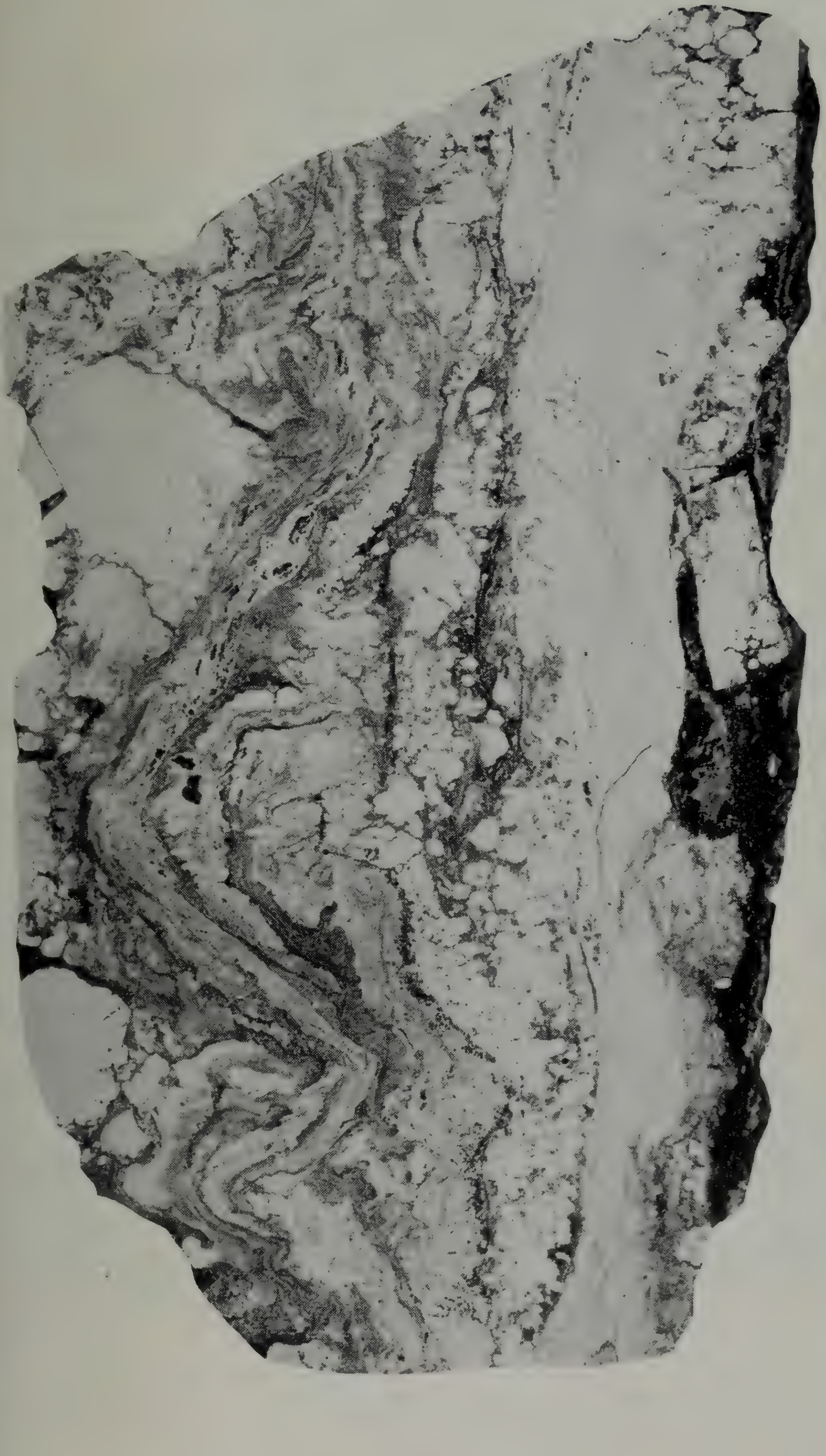
[34] Huey, Arthur S., Geology of the Tesla quadrangle, California: California Div. Mines Bull. 140, 75 pp., 1948.

[35] Op. cit.

[36] Taliaferro, N. L., op. cit., p. 154.
Ampferer, O., and Hammer, W., Die basischen Intrusivmassen Westserbiens: Akad. Wiss. Wien, Denkschr, vol. 98, pt. 1, pp. 11-15, 1923.
Benson, W. N., The geology and petrology of the great serpentine belt of New South Wales: Linnean Soc. New South Wales Proc., vol. 38, pp. 662-724, 1913.

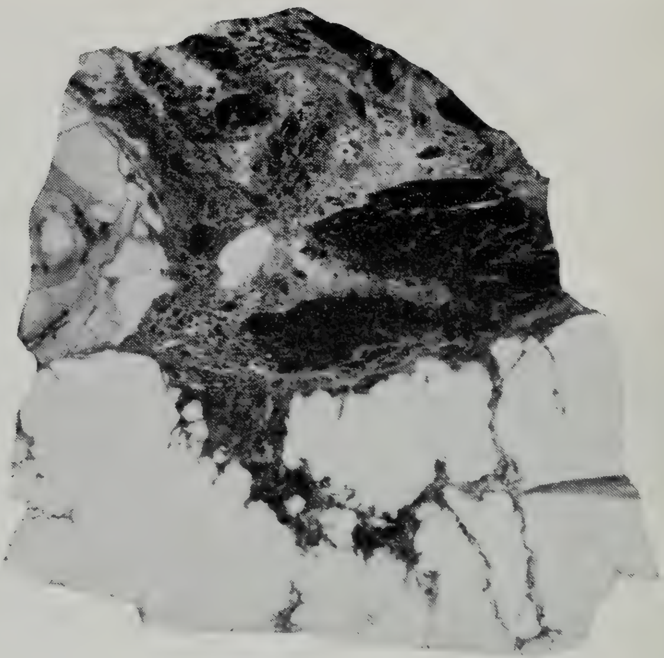
[37] Op. cit.

[38] Op. cit., p. 153.



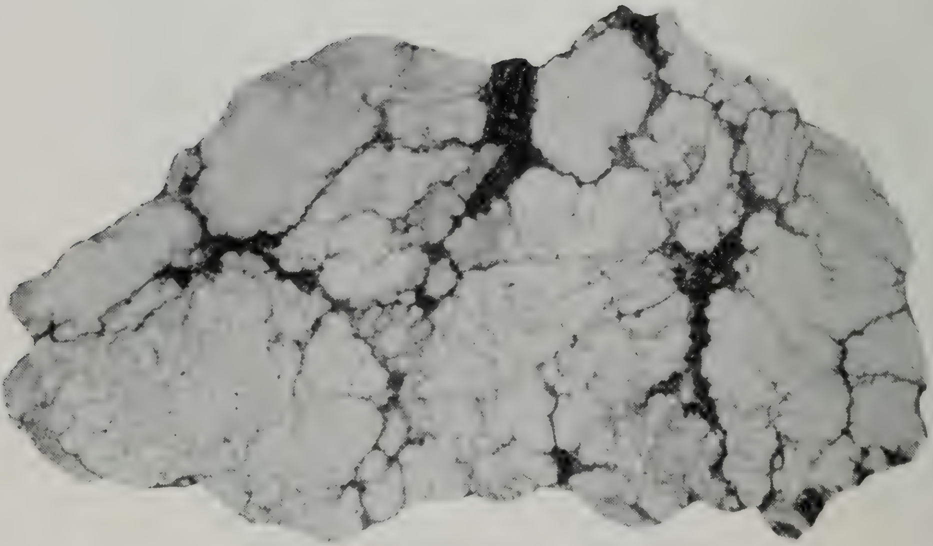
MYLONITIZED AND BRECCIATED MAGNESITE

Contorted layers contain finely ground serpentine and are various shades of pink. Mylonite layer at base of specimen contains some angular fragments of brecciated magnesite. Between are nodules only partly broken. Photograph natural size.

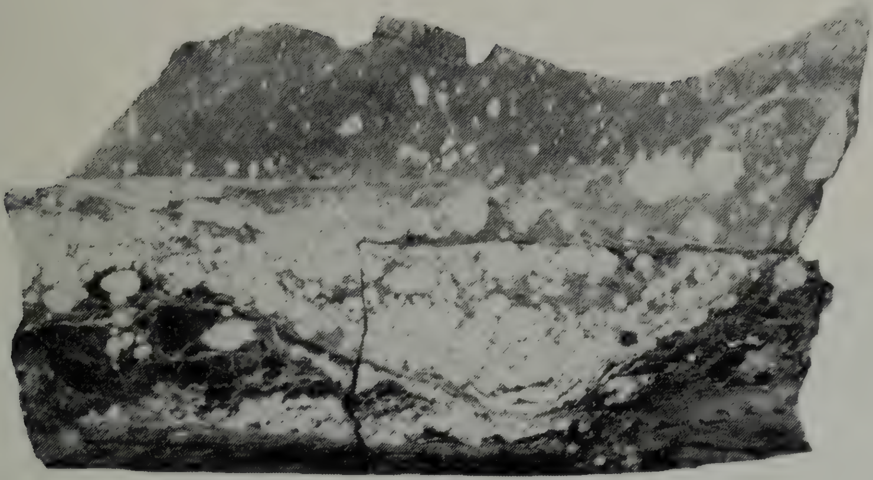


NODULAR MAGNESITE

A, Nodules in serpentine breccia containing impregnation of magnesite. Magnesite on upper left side is fractured by desiccation. Magnesite at lower right contains a primary lunate fissure.

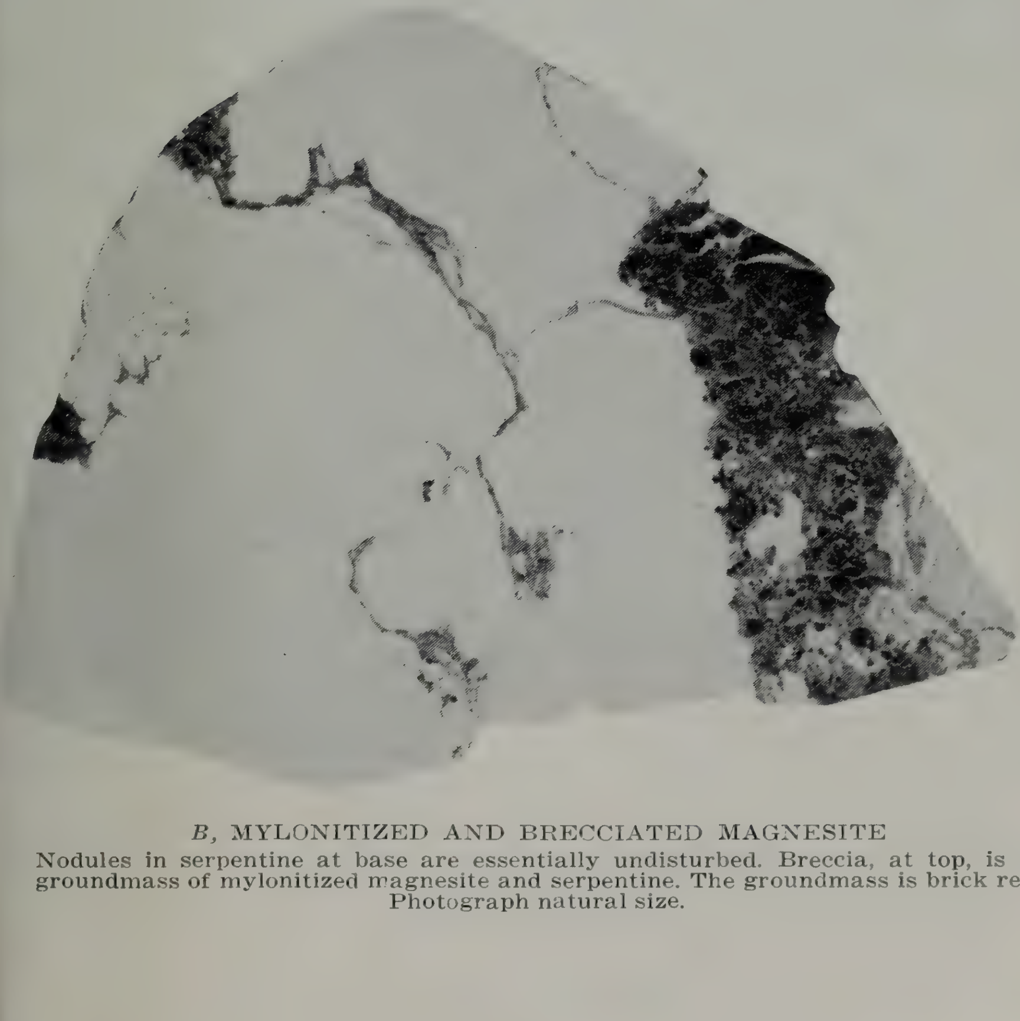


B, Semicoalesced magnesite nodules in serpentine showing development of cauliflower shape. Note sharp contacts with serpentine. Photographs natural size.



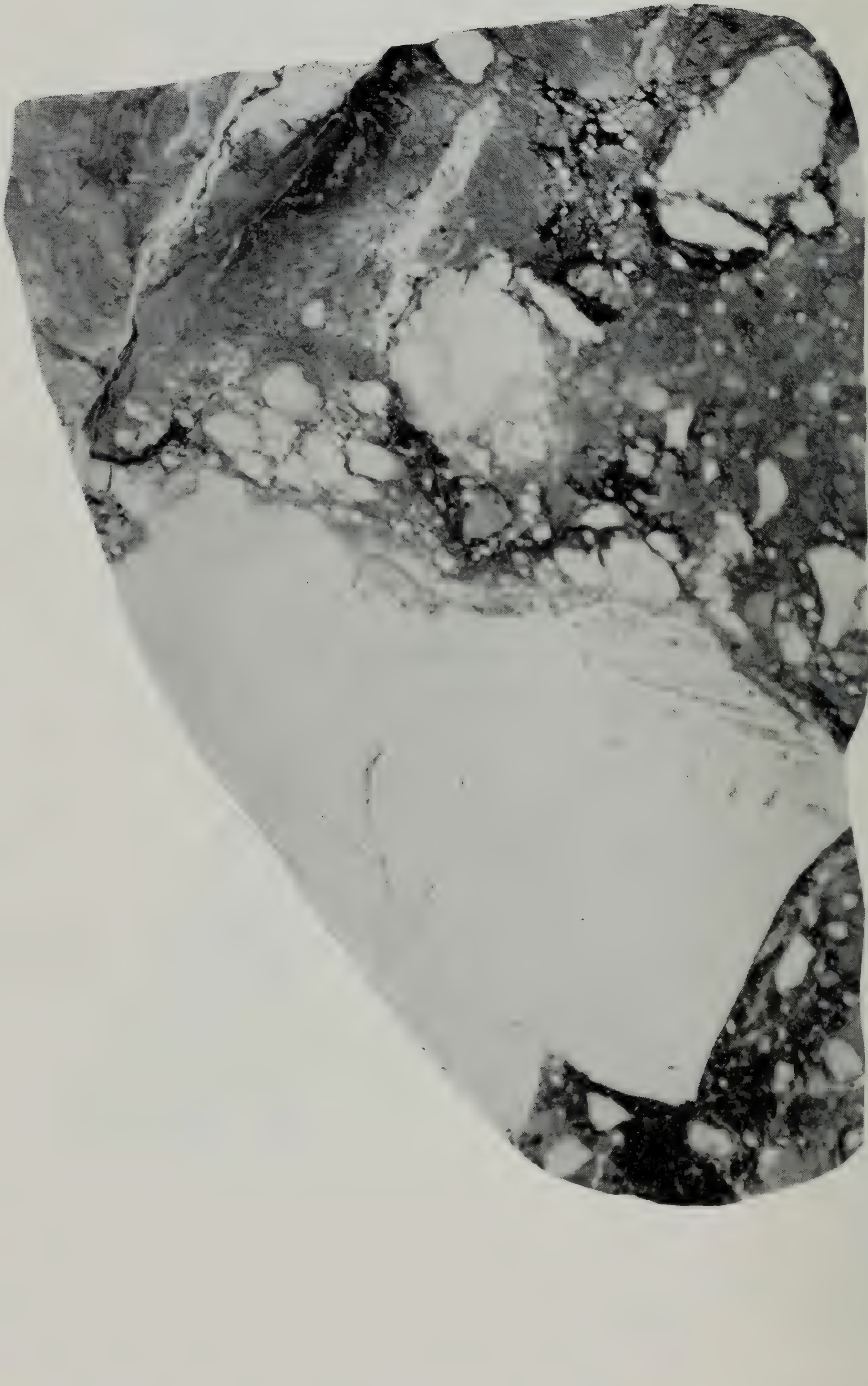
A, MAGNESITE CONTAINING UNREPLACED SERPENTINE

Almost completely coalesced nodules are separated by thin selvages of serpentine in sutures. Serpentine at right is brecciated and partly impregnated by magnesite. Photograph natural size.



B, MYLONITIZED AND BRECCIATED MAGNESITE

Nodules in serpentine at base are essentially undisturbed. Breccia, at top, is in groundmass of mylonitized magnesite and serpentine. The groundmass is brick red. Photograph natural size.



MYLONITIZED AND BRECCIATED MAGNESITE

The groundmass, colored gray and pinkish gray, consists of finely ground magnesite and serpentine. Photograph natural size.

grains are twinned. Olivine, together with chromite, crystallized first, followed by enstatite.

A specimen of brown-green peridotite from the Western mine area was collected for analysis. It contains a magnesite veinlet, which is not characteristic of all peridotite from this area (see table 2). It was collected by Eugene Callaghan, analyzed by Charles Milton, and its norm and micrometric measurement were made by G. T. Faust, all of the Geological Survey. This specimen is of the harzburgite or saxonite variety. It contains olivine very high in forsterite, the magnesium silicate end member of the forsterite-fayalite series. A rock of similar mineral and chemical composition, collected from British Columbia by R. A. Daly, is classified by Albert Johannsen [39] as an olivinite.

Specimen CW-2 is partly serpentinized, light-green peridotite from the Western mine area. It contains less enstatite than specimen CW-4, and its composition is almost that of a dunite (see table 3). It was collected by Eugene Callaghan, and its micrometric measurement was made by G. T. Faust.

The peridotite weathers to brick-red and reddish-buff colors. On weathered surfaces, the cleavage planes of the pyroxene are conspicuous. Close spacing of fractures causes the rock to break into small blocks

Table 2. Analysis of peridotite specimen CW-4, Red Mountain, Santa Clara County, California.

Chemical analysis [1]		Micrometric measurement [2]		Norm [3]	
	Percent		Percent		Percent
SiO_2	42.75	Olivine	80.8	Olivine Fo	65.10
Al_2O_3	0.35	Enstatite	12.7	Fa	7.14
Fe_2O_3	1.72	Serpentine	3.3		
FeO	7.03	Opaque minerals	0.8	Wo	0.35
MgO	45.40	Magnesite	2.4	Pyroxene En	19.00
CaO	.037			Fs	1.85
Na_2O	trace		100.0		
K_2O	none			Magnetite	2.55
H_2O+	1.60			Chromite	0.90
H_2O-	0.09			Magnesite	2.69
TiO_2	trace			Anorthite	0.83
CO_2	0.74				
SO_3,S	none				100.21
Cr_2O_3	0.28			Classification:	
NiO	0.04			C.I.P.W.	
CoO	none			V.1.4.1.1.	
MnO	0.10				
	100.47				

[1] Analysis made by Charles Milton.

[2] Percentage by weight. Micrometric measurement made by G. T. Faust. The average of two micrometric measurements on two thin sections is given.

[3] Norm calculated by G. T. Faust.

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[39] Johannsen, Albert, A descriptive petrography of the igneous rocks, vol. 4, p. 421, Chicago, University of Chicago Press, 1938.

Table 3. Micrometric measurement of peridotite specimen CW-2, Red Mountain, Santa Clara County, California.[1]

	Percent
Olivine	68.8
Enstatite	6.7
Serpentine	23.8
Opaque minerals	0.7
	100.0

[1] Percentage by weight. Micrometric measurement made by G. T. Faust.

a foot or less in diameter. Continuous exposures more than 100 feet in length are rare, and even on the spurs of ridges, where exposures are most numerous, most of the areas free of soil and vegetation are covered with loose scree derived from the bedrock immediately below. Weathering is deepest in the valleys and swales, and causes the peridotite to break down to a conspicuously colored brick-red soil, very sticky and claylike when wet.

Dunite. Dunite is a rock consisting almost entirely of olivine, and only very small amounts of the accessory mineral chromite. All dunite bodies studied in this area were extensively serpentinized, so the original mineral content and grain size could not be ascertained. Microscopic studies of fragments show that serpentinization affects from 75 to 100 percent of the rock. Some olivine and chromite survive alteration where serpentinization is incomplete. A few grains of the aggregate, bastite, indicate that enstatite probably was a primary constituent of the rock before alteration.

One specimen of fresh dunite contained olivine grains ranging from 2 to 3 millimeters in length. Typical material in dunite bodies at Red Mountain is dark-green massive serpentine, containing primary chromite and secondary magnetite. The dunite weathers light buff to dun color and breaks conchoidally into small chips. Dunite areas are conspicuous because little vegetation covers the smooth dun-colored slopes surfaced with weathered serpentine chips.

H. E. Hawkes Jr.[40] believes the dunite to be intrusive into the peridotite. In the area here studied, contacts of the larger dunite bodies with peridotite in most places are somewhat sheared, obscuring primary relationships, but small bodies are gradational enstatite-free phases of the peridotite.

Pyroxenite. Pyroxenite bodies at Red Mountain consist of coarse-grained concentrations of pyroxene occurring as small lenses and pods and also as dikes in joints and fractures of the peridotite. The larger pyroxene-rich bodies, as much as several feet long, in most places are near peridotite-dunite contacts. Pyroxene filling joints obviously is younger than the peridotite, but the age of the larger bodies was not determined. The pyroxenite consists of diopside, enstatite, and minor amounts of olivine, all of which minerals may occur as crystals as much as several inches in length.

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[40] Op. cit.

Alteration of Peridotite and Dunite. In this district, all intrusive rocks are altered to serpentine in various degrees. Serpentinization of peridotite is confined to zones of fracture and shear and has affected a very small percentage of the rock, whereas the larger dunite bodies are almost completely serpentinized. Most pyroxenite is only slightly serpentinized.

In the peridotitic parts of the complex at Red Mountain, the extent of fracturing and shearing governs the degree of serpentinization. Along joints and irregular small fractures, serpentine occurs only in narrow bands on both sides of the parting, whereas large shear zones several feet wide may consist entirely of serpentine. Such serpentinized shear zones are the sites of most magnetite deposits. In areas where regular joints are the only fractures in the rock, each block is faced by a thin selvage of serpentine, but the interior of the block is entirely fresh; such material is named ''blocky peridotite'' on mine maps.

There are two types of serpentine. One is massive, has a dull luster, and is dark green or dark green with a reddish cast. The massive serpentine occurs only where there has been no movement after serpentinization, or where failure has been by brecciation rather than shear during post-serpentine deformation. This type is found in dunite and also in the wider shear zones in peridotite, where some brecciation occurred. The second type is sheared serpentine. The luster of sheared serpentine is greasy, because of innumerable slickensided shear planes in the material. The color ranges from dark green to green, the lighter shades being characteristic of the more strongly sheared serpentine. This type is the more common in the peridotite shear zones, but it may contain angular fragments of massive serpentine and nearly unaltered peridotite in any proportion.

Microscopic study indicates that the serpentine consists mainly of antigorite and includes only minor amounts of chrysotile. The antigorite replaces olivine and enstatite, growing from fractures and partings into the primary minerals. In olivine, antigorite first develops as cross-fibered material, the long axes of individual crystals being normal to the fracture or parting. With further growth, the blades develop radially and interference with other radial groups produces a felted pattern. Simultaneously, magnetite forms in the antigorite, its distribution indicating the usual relict structure of replaced olivine grains. Alteration of enstatite results in bastitic serpentine. As in olivine, replacement proceeds from the fractures or partings. In contrast with the alteration product of olivine, serpentine replacing enstatite is very fine-grained and is not accompanied by magnetite; instead, bastitic pseudomorphs after enstatite are limonite-stained. In thin section the contrast is marked; along any one fracture, the type of serpentinization changes sharply at all olivine-enstatite contacts.

Where the serpentine has been sheared, all primary structures are destroyed. Antigorite crystals are bent and broken, and may be recrystallized. Some such recrystallized blades of antigorite may be an inch long. Others are imperfectly recrystallized, for microscopic study shows the long blades to be mosaics of smaller grains.

Magnesite is always bordered by serpentine, even where veinlets cut into fresh peridotite. Such serpentine borders always are narrow, a fraction of the magnesite vein width. It is concluded that solutions depositing magnesite can alter peridotite; the resulting serpentine is of the massive type.

F. L. Hess,[41] E. Clar,[42] and others have commented on the altered appearance of serpentine in the vicinity of magnesite deposits. They conclude either that serpentine was altered to magnesite in place, or that magnesite-bearing solutions have altered serpentine. These statements are not in accord with the relations observed in the Red Mountain district. The only alteration of serpentine by such mineralizing solutions in the deposits at Red Mountain is the oxidation of included magnetite to limonite, which stains the serpentine yellow. Where serpentine seemingly is bleached in the vicinity of magnesite bodies, thin-section study shows that the lighter color is due to the presence of magnesite in numerous closely spaced fractures visible only under the microscope.

In this district, the main serpentinization of peridotite was associated with deformation of the intrusive body, as shown by the constant association of serpentine with shears and fractures and by the fact that it is most complete in the larger shear zones where movement during deformation was greatest. The extent of serpentinization by solutions depositing magnesite is considered to be small. In the peridotite at Red Mountain it is not a deuteric feature, as suggested for other regions by F. G. Wells,[43] by H. H. Hess,[44] and by W. N. Benson.[45] Neither is it a product of surface weathering, a view adopted by earlier authors,[46] because it bears no relation to topographic surface and there is no evidence that it is forming through surface weathering at the present time.

The complete or nearly complete serpentinization of the large dunite bodies in this district was not studied in connection with the investigation of the magnesite deposits. In contrast with the localized serpentinization of peridotite, the widespread alteration of dunite may be deuteric as discussed by F. G. Wells [47] and H. H. Hess.[48]

Structures in the Intrusive Body of Red Mountain

Brief mention has been made of the faults bordering the intrusive body of Red Mountain and the faults between the peridotite and dunite. They do not noticeably affect the areal distribution of rocks and are not marked by strong physiographic expression, and therefore probably have small displacement.[49]

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[41] Op. cit., pp. 17-20.

[42] Clar, E., Mikroskopische Untersuchungen an der Magnesitlagerstätten von Kraubath in Steiermark: Zeitsch, prakt. Geol., vol. 36, pp. 97-99, 1928.

[43] Wells, F. G., The hydrothermal alteration of serpentine: Am. Jour. Sci., 5th ser., vol. 18, p. 52, 1929.

[44] Hess, H. H., The problem of serpentinization and the origin of certain chrysotile asbestos, talc, and serpentine deposits: Econ. Geology, vol. 28, pp. 652-656, 1933.

[45] Benson, W. N., The origin of serpentine, a historical and comparative study: Am. Jour. Sci., 4th ser., vol. 46, pp. 693-729, 1918.

[46] Van Hise, C. R., A treatise on metamorphism: U. S. Geol. Survey Mon. 47, pp. 475-476, 1904. . . . Beyschlag, F., and Krusch, P., Die Erzlagerstätten von Frankenstein u. Reichenstein in Schlesien: Pruess. geol. Landesanst Abh. (Berlin), Band 73, pp. 6-22, 1913.

[47] Op. cit., p. 52.

[48] Op. cit.

[49] Hawkes, H. E. Jr., and others, op. cit., p. 90.

In addition to these faults, the intrusive body is cut by shear zones and joint systems. Although displacement seems to have been of small magnitude along these internal shear zones, they are of great importance to the localization of the magnesite deposits and therefore will be described in some detail.

Two major systems of shear zones are seen in the area studied in this investigation. The first system consists of long, regular, and nearly parallel shear zones, trending northwest and dipping northeast. The second system consists of comparatively short and irregular shear zones, usually trending north and having variable dips.

The long, regular shear zones of the first system branch in places, the splits leaving the main zones at small acute angles on either side of the main shear and trending either northwest or southeast. This system can be seen more clearly in aerial photographs than on the ground; the zones are marked by slight differences in the vegetation, probably best attributed to difference of soil or supply of ground water.

Parallel to the shear zones are numerous minor shear planes forming the strongest element of joint system. Very few of the shear joints maintain constant attitudes for even short distances but instead are gently sinuous. Where closely spaced, they form sheeting structure in the perodotite. Cross joints are less regular, shorter, and discontinuous across the stronger shear set. Quite possibly they are older than the shear joints, but they do not influence the orientation of the latter, and therefore it is probable that both the shear set and the cross joints were formed at the same time. Typical of this joint system are the following sets, measured in the vicinity of the White Diamond-Silver area:

Major set	Cross joints	
N. 54° W.; 28° NE.	N. 30° E.; 67° SE.	N. 90° E.; 78° S.
N. 40° W.; 74° NE.	N. 22° E.; 45° NW.	N. 85° E.; 49° SE.
N. 35° W.; 35° NE.	N. 25° W.; 50° SW.	N. 75° W.; 70° NE.
N. 49° W.; 40° NE.	N. 26° W.; 80° SW.	N. 33° E.; 35° NW.

In the northern part of the White Diamond-Silver area, the major shear joints strike northeast and dip northwest. This is the only area where the latter orientation prevails. No marked structural break occurs between this area and the area cut by the northwest-trending set. Evidently, the stresses were not uniform throughout the intrusive body at the time of deformation.

The short, northward-trending shear zones of the second major system are more irregular in strike and dip and generally are wider than the zones of the first system. The shear zones of this second system cut across the zones of the first system, and therefore must have formed at a later period. Most of the magnesite bodies are in the shear zones of the second system.

Because the main joint system is related to the earlier shear-zone system, detailed study of joints gives no information as to the structure of the second shear-zone system, which carries most of the major magnesite bodies. Near the larger magnesite veins the fracture pattern frequently is very complex, for these areas were fractured not only during the formation of the shear systems previously described, but also by the repeated movements which occurred during subsequent mineralization.

The earlier, northwest-trending shear system probably was produced during the orogeny which folded the sedimentary rocks of the Franciscan formation. Although the directions of operative stresses were not determined in this study, the effective compressive stress undoubtedly was northeast-southwest, normal to the axis of the folds in the sedimentary rocks and to the trend of the shear zones themselves. The stresses forming the second shear system were tensional and were oriented east-west.

MINERAL DEPOSITS

Mineralization at Red Mountain resulted in the deposition of carbonate, silica, and magnesium silicate minerals. The magnesite was deposited mainly as a replacement of serpentine and to some extent as fissure-filling material. Post-magnesite minerals all were deposited as fissure fillings. The deposits are in serpentinized shear zones and are localized to a high degree by the vein structures. The mineralization appears to have been at shallow depths and derived from low-temperature hypogene solutions.

Mineralogy

In the following pages, the minerals are described in order of their deposition at Red Mountain.

Magnesite. The theoretical composition of magnesite is MGO, 47.6 percent; CO_2, 52.4 percent. The specific gravity of cryptocrystalline magnesite is 2.94 according to Carl Hintze,[50] whereas H. Leitmeier [51] states that it ranges from 2.9 to 3.0. G. Petunnikov [52] finds that the specific gravity varies from 2.11 to 2.92 in Serbian magnesites, and is inversely proportional to the porosity; specific gravities less than 2.59 are unusual. The hardness of magnesite, according to Dana, is from $3\frac{1}{2}$ to $4\frac{1}{2}$. However, the hardness of the cryptocrystalline variety, being dependent in large part on the degree of cohesion between grains, may be considerably less than $3\frac{1}{2}$, and some material at Red Mountain is quite chalky. The mineral may dissolve slowly in cold dilute hydrochloric acid.[53]

The magnesite in these deposits is cryptocrystalline, massive, brittle, and has a dull luster. Fractures are conchoidal, and the broken material resembles unglazed porcelain. Most magnesite is dead white, but included residual serpentine may tint it light green. Where mylonitized and mixed with serpentine from the surrounding country rock, the magnesite is gray, pink, or, in a few places, brick red.

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[50] Hintze, Carl, Handbuch der Mineralogie, Band 1, 3te Abt., erste Halfe, p. 3114, Berlin and Leipzig, 1930.

[51] Leitmeier, H., Magnesite, in Doelter's Handbuch für Mineralchemie, vol. 1, p. 222, Steinkopf Press, 1912.

[52] Petunnikov, G., Ueber einige Eigenschaften der serbischen Magnesit: Mont. Rundschau, vol. 21, pp. 276-277, 1929.

[53] Petunnikov. G., op. cit., pp. 278-279.

Microscopic study shows that most of the magnesite of Red Mountain is homogeneous and extremely fine grained or cryptocrystalline. In thin sections of small nodules, concentric layers may vary slightly in grain size. Comparatively coarse-grained carbonate seen under the microscope at some magnesite-serpentine contacts probably is dolomite.

The mineral is compact, but a few vugs and lunate openings up to 2 centimeters long and 3 millimeters wide are present. The latter frequently are associated with slickensided shear planes and therefore probably are of tensional origin. Such small openings may be lined with thin films of opal. Small open cracks are produced by desiccation when the mineral is exposed to air.

The magnesite in these deposits is very pure. Random samples analyzed by the Geological Survey show but minor amounts of insoluble material (either silica minerals or serpentine), as much as 3 percent calcium carbonate, and only traces or complete absence of iron oxide and alumina (see table 4). Analyses by the operating company show that the magnesite also contains an average of 0.2 percent free H_2O, with a range from 0.04 to 3.3 percent.[54]

Table 4. Analyses of magnesite, Western mine, Santa Clara and Stanislaus Counties, California.

Joseph J. Fahey, Analyst

	51-b	56-c	59-b	62-b	65-a	73
Insol.	0.04	0.04	0.04	0.96	0.02	3.12
R_2O_3[1]	0.10	none	none	0.02	none	[2] 0.26
$CaCO_3$[3]	3.07	0.21	2.64	1.39	0.53	0.03
$MgCO_3$[3]	95.22	99.11	96.52	96.63	98.74	95.83
Totals	98.43	99.36	99.20	99.00	99.29	99.24

[1] Trivalent iron and alumina oxide.

[2] Fe_2O_3, 0.16 percent.

[3] **Computed on the determined figures for CaO and MgO.**

Specimen	CW 51-b	No. 65 vein (Diamond Vein), T. 6 S., R. 5 E., Mount Diablo Meridian.
	CW 56-c	Silver two vein, T. 6 S., R. 5 E.
	CW 59-b	Lower No. 12 vein, T. 6 S., R. 4 E.
	CW 62-b	Pacific vein, T. 6 S., R. 5 E.
	CW 65-a	No. 6 vein, footwall, T. 6 S., R. 5 E.
	CW 73	No. 1 vein, T. 6 S., R. 5 E.

Specimen CW 62-b has a higher content of insoluble material because small fractures throughout the magnesite are filled with silica. Specimen CW 73 is mylonite containing finely ground serpentine (see pl. 34). The 3.12 percent content of insoluble material represents a serpentine content of approximately 6.8 percent. Although most hand specimens have low silica content, material extracted in mining operations may run considerably higher in this impurity, chiefly because of serpentine adhering to the magnesite.

The calcium carbonate reported occurs as very small dolomite veinlets in magnesite and probably as disseminated dolomite in the magnesite. Such material is very fine-grained and usually requires chemical analysis for its determination. Magnesite bodies with a high calcium content do not have systematic distribution, nor are they related to the proximity of calcite veins. Most of the mined material contains about 2 percent calcium oxide, although several samples have contained as much as 7 percent calcium oxide (see table 8).

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[54] Courtesy of the Westvaco Chlorine Products Corporation.

The magnesite also contains minor amounts and traces of other elements. Table 5 gives the results of spectrographic examination of specimen CW 51-b, made by K. J. Murata, of the U. S. Geological Survey. Of these minor constituents, only the silica and manganese-bearing minerals can be seen megascopically.

Dolomite. Dolomite cannot be seen megascopically. Under the microscope it is observed in very small veinlets and along some magnesite-serpentine contacts. Rarely it forms small pellets having radial extinction under crossed nicols. The dolomite is slightly coarser grained than the magnesite, and its distribution in the magnesite bodies is irregular. It provides the calcium of the magnesite ore. Dolomite is deposited after magnesite and its presence indicates that some calcium entered the mineralizing solutions at the end of this stage of mineralization.

Manganese Oxide. Dendrites of an unidentified manganese oxide occur sparingly in fractures and in sutures between coalesced magnesite nodules. This material was deposited after the magnesite and dolomite, and probably before the silica and magnesium silicate minerals.

Silica and Magnesium Silicate Minerals. The silica minerals and magnesium silicate minerals occur principally in the shear zones, but also are found throughout the country rock in small amounts. In the shear zones, they are most common in the shear planes which form the hanging walls and footwalls. Throughout the district the minerals were deposited in open fissures.

Table 5. Spectrographic examination of magnesite from Western mine, No. 65 vein (Diamond vein), specimen No. CW 51-b.

ANALYST, K. J. MURATA

Major elements: (>1%) : Mg, Ca.
Minor elements: (.01%-1%) : Fe, Si, Sn, Mn.
Traces: (.00X%) : Na, K, B, Cu, Pb, Bi, Al, Ba.
Absent: F, P, As, Sb, Ge, Ag, Mo, W, Zn, Cd, Cr, V, Co, Ni, Sr, Li, Ti, Y, Yb, La, Ga, In, Tl.

Note: Electrodes of special purity were used in order to establish the presence of Na, K, B, and Cu.

Chalcedony was the first mineral of this group to be deposited. It is hard, fine-grained, has a waxy luster, and is colored cream, buff, and orange buff. It is cryptocrystalline to extremely fine-grained, as observed under the microscope. The darker varieties are younger than the lighter varieties.

Opal, deposited after the chalcedony, is either clear, colorless, and translucent, or opaque and colored milky white to red brown. Its luster is subvitreous for the clear material and resinous for the opaque material. The opaque varieties are fractured and cemented by the clear opal. Vein deposits of this mineral are very vuggy and porous. Opal is also deposited as thin films in some small vugs in magnesite and chalcedony.

Deweylite, a hydrous magnesium silicate of the serpentine group, followed opal in deposition. It is semitransparent, has resinous luster and hardness from 2 to 3. It is cryptocrystalline and is cream-colored to orange-buff. The mineral decrepitates rapidly on loss of water and also fractures when remoistened. It was identified by means of thermal analysis by G. T. Faust, of the U. S. Geological Survey. Deweylite frequently is mixed with opal, so deposition of the deweylite may have started before the close of opal deposition. Most of it, however, was deposited after the opal; some of the mixing was facilitated by the vuggy primary structure and secondary shattering of the latter.

A second hydrous magnesium silicate mineral, younger than the deweylite, is tentatively identified as sepiolite. It is dense, nearly opaque, has waxy luster, and can be marked by the fingernail. It is orange brown in color and has a conchoidal fracture. Like deweylite, it picks up and loses water rapidly and fractures readily in the process. The cryptocrystalline aggregates have an index of less than 1.54. A green variety of this mineral also occurs in minor amounts in some veins.

Another mineral, unidentified as yet, is thought to be a magnesium silicate. It is very soft and white, moist when fresh, and dries to a flaky powder. It was the last of this group of minerals to be deposited.

Calcite. Calcite is the last mineral deposited in the veins of this area. It is medium to coarse grained in texture and white to light gray. It is fissure-filling material, and unlike dolomite, never impregnates the magnesite, for its presence in shear planes adjacent to magnesite bodies does not raise the calcium content of the magnesite ore. Calcite has unusual distribution in that it is found only in two areas, the westernmost deposits of the Western mine, and along the footwall of the main vein in the eastern deposits. This distribution is in contrast to the minerals described above.

Aragonite. Aragonite, another calcium carbonate mineral, is being deposited as sinter at the present time in the beds of nearly all intermittent streams that originate in this part of the intrusive body of Red Mountain. Analyses of waters from these streams and springs show a much higher magnesium content than calcium content (see table 6), but

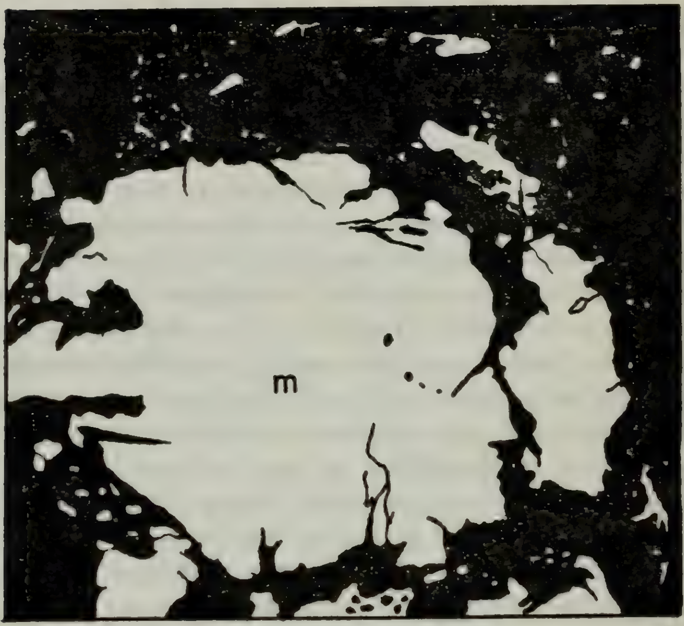
Table 6. Analyses of stream and spring waters, Red Mountain district.[1]

	A	B	C
Calcium (Ca)	2.5	3.5	n.d.[2]
Magnesium (Mg)	112	130	n.d.
Sodium (Na) Potassium (K)	30	20	66
Bicarbonate (HCO_3)	640	696	580
Sulfate (SO_4)	.8	3.0	2
Chloride (Cl)	4	9	18
Dissolved solids Sum-p.p.m.	465	508	n.d.
Total hardness as $CaCO_3$	408	542	390
Specific conductance Kx10^5 at 25° C.	82.3	93.9	78.5

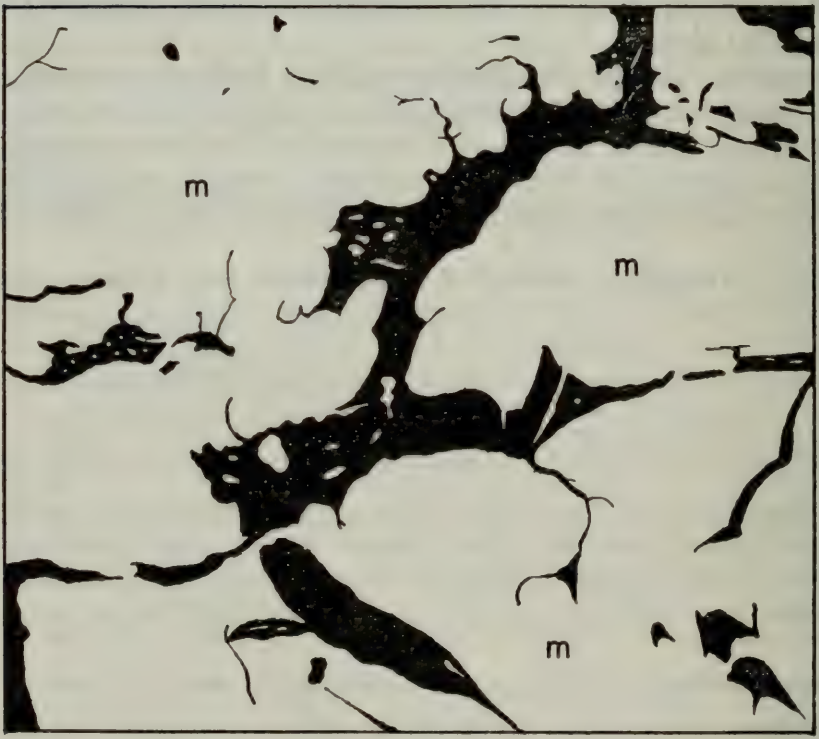
[1] Analyses by Albuquerque, New Mexico, laboratory, Water Resources Branch, U. S. Geological Survey, in parts per million.

[2] Not determined.

A. Waters issuing from portal of lower drift, Red Mountain mine, Stanislaus County, California.
B. Spring east of the Western mine camp, used for camp and mine purposes.
C. Spring in NE¼, sec. 18, T. 6 S., R. 5 E.



A, Large magnesite nodules in serpentine.



B, Nodular magnesite replacing serpentine.

FIGURE 2.

deposited material contains only 2 to 5 percent magnesia.[55] Some of the sinter deposits are fairly large; the Bureau of Mines estimates from 21,000 to 28,000 tons in the deposit below the Red Mountain mine (see pl. 38).

The water sample used to make analysis C, table 6, was too small to determine its calcium and magnesium contents, but C. S. Howard of the Water Resources Branch, U. S. Geological Survey, comments that the hardness value for the water indicates a high concentration of magnesium and/or calcium. Analyses A and B show that the dissolved constituents of the water were chiefly magnesium and bicarbonate.

Textures of Magnesite as Related to Deposition

Most magnesite in these deposits is nodular, and the remainder occurs as fracture fillings in narrow veins. The textures of magnesite in the large serpentinized shear zones consist of both types of aggregates, whereas in the relatively unserpentinized peridotite between shear zones, the magnesite is mainly fracture filling.

Nodular bodies range in size from 1 millimeter or 2 millimeters to several feet in diameter. Small nodules are round but larger ones are less regular in shape. The spherical surface of small nodules changes to mammillary or tuberous surfaces on larger nodules (see pl. 35, fig. 2*A*). The larger nodules can best be described as cauliflower-shaped. The shape of nodules is modified by external factors which curtail uniform development. These include the presence of other nodules, peridotite blocks which are not easily replaced, and shear planes.

The nodules may be thinly scattered in serpentine or may be closely packed and coalesced, complete gradation existing between the two extremes (see pl. 36*A*, fig. 2*B*). Coalesced aggregates may have any shape whatever, depending on distribution and size of individual nodules as well as the nature of the host rock and structural features. Nodular aggregates may form lenses of massive magnesite as much as 65 feet long and 15 feet wide, but most lenses are smaller and contain some serpentine and peridotite inclusions.

The internal structure of the nodules is concentric and contacts between the magnesite and serpentine always are sharp unless postmineral movement, such as mylonitization, destroyed the primary structures. These features, together with the nodular shape, indicate that this type of magnesite body probably was deposited as a colloid. Growth started from a nucleus, and accretion of magnesite and replacement of serpentine occurred at the surface of each nodule. As angular peridotite and massive serpentine fragments are included within magnesite bodies it is inferred that the sheared serpentine was the most readily replaced of these types of country rock. The massive serpentine inclusions in the magnesite nodules may have been altered from peridotite during the period of magnesite deposition, for it has been noted that the mineralizing solutions have produced such alteration.

The other principal mode of occurrence of magnesite is that of narrow veins which have comparatively regular contacts with the country rock. Among the structures containing such magnesite veins

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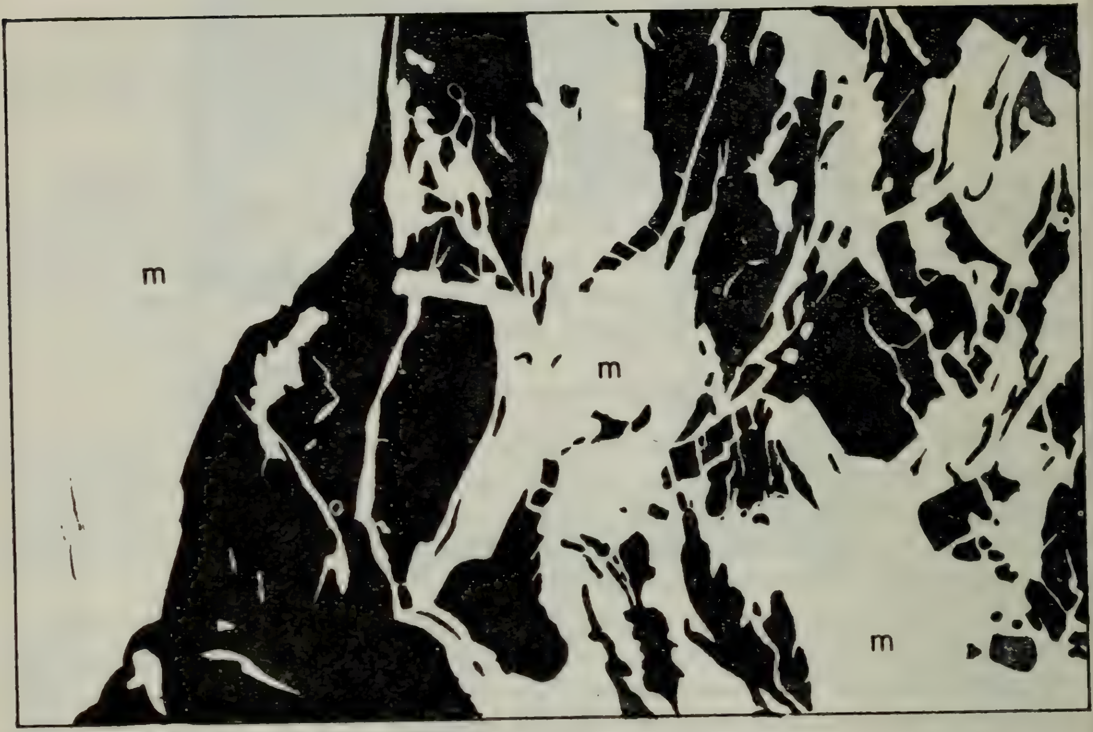
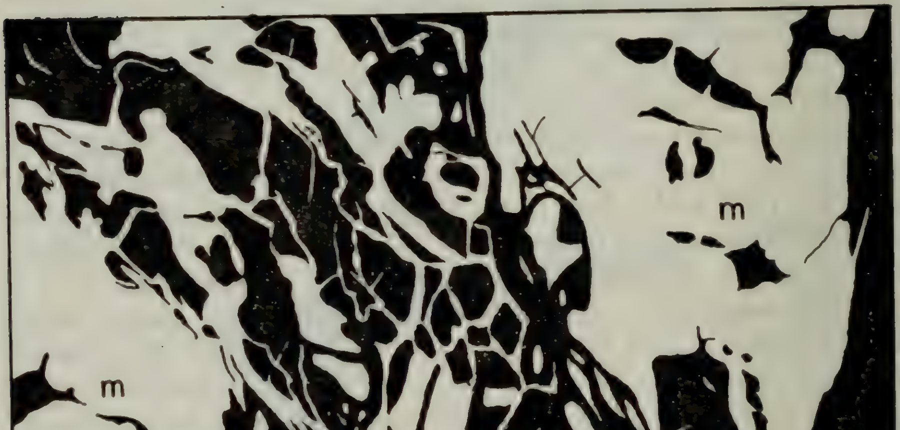
[55] U. S. Bureau of Mines, op. cit., pp. 10-12.



A, Replacement and fissure-filling magnesite.



B, Replacement and fissure-filling magnesite.

FIGURE 3

are joints, tension fractures, irregular fractures, shear planes, anastomosing vein systems, and breccia zones (see pl. 3). It is clear that these veins were formed by the deposition of magnesite in open fissures, both in serpentine and in peridotite.

Many shear zones containing fissure-filling deposits are subsequently enriched by replacement magnesite (see pl. 4). Some veins that appear to be fissure fillings actually consist of coalesced nodules, as shown by the sutures throughout the solid material. The map of the west split of Silver One vein, south ore body, shows many textures and structures of magnesite deposited in a wide shear zone both by replacement and by fissure filling (see pl. 40).

Proof that the large lenses of magnesite are of replacement origin is found in the gradation from massive material to nodular material, and by the internal structure of the magnesite which frequently shows the sutures between coalesced nodules (see pls. 35, 36, fig. 2*B*). Banded structure resulting from lateral accretion during expansion of open fissures does not occur in the magnesite bodies of the Red Mountain district.

Because nodular magnesite furnishes the bulk of the ore, the size and spacing or degree of coalescence of nodules is most important to mining operations. Magnesite-serpentine contacts are irregular and tight, and the ore cannot be completely freed of serpentine. On the underground maps, the ore is classified roughly by size of nodules, which gives an index of the serpentine content of the broken ore: nodules larger than 1½ feet in diameter furnish high-grade magnesite; nodules from 6 inches to 1½ feet in diameter furnish medium-grade magnesite; and nodules less than 6 inches in diameter furnish low-grade magnesite.

Weathering of Magnesite

Magnesite is weathered rather easily by surface waters, especially in swales where the amount of ground water is greatest. Solid magnesite veins as wide as 10 feet may have no surface showing whatever. Usually the completely leached zone is confined to the soil cover, the underlying bedrock containing partly leached magnesite to within a few feet of the soil contact. Float works up to the surface during soil movement and may be the sole indication of the presence of a magnesite vein. F. L. Hess [56] reported that ground water cut channels through massive magnesite, some of which were large enough to be used as ore passes. Along ridge crests and shoulders, where less ground water accumulates, magnesite croppings tend to be more extensive, but are scarce even there. When exposed to weathering, magnesite develops a peculiar rough surface consisting of irregular sharp projections and pits with relief of as much as an inch. The pattern may possibly be explained by desiccation of magnesite on exposure, or by brecciated structure in the magnesite, but neither of these accounts for the curving sets of intersecting lines seen on many outcrops.

Structures of the Magnesite Veins

The magnesite deposits of commercial size are limited to serpentinized shear zones, although minor amounts of the mineral also occur

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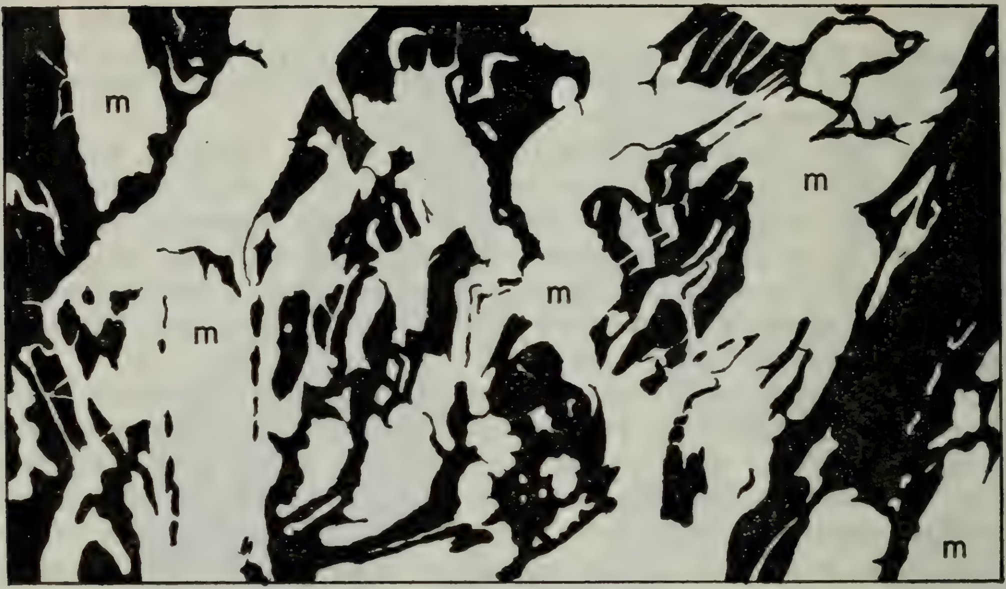
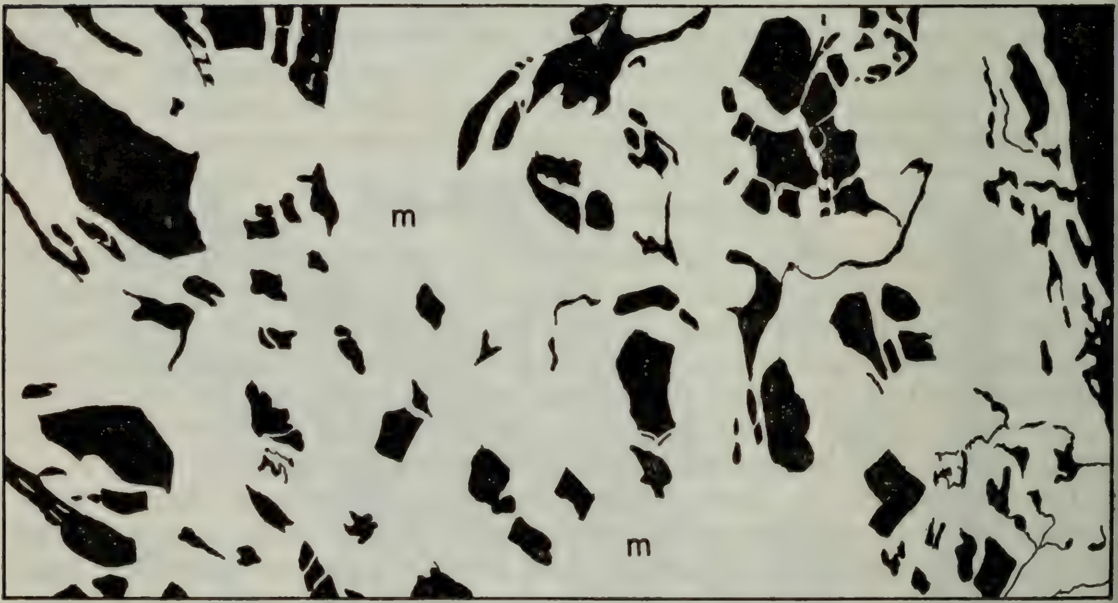
[56] Op. cit., p. 36.



A, Magnesite replacing serpentine.



B, Replacement magnesite in a breccia zone.

FIGURE 4

in the relatively unserpentinized country rock. This relationship indicates that structure controls the sites of deposition. In studying this district it was found that the structural control also extended to localization of magnesite bodies in the shear zones and to localization of high-grade shoots within magnesite bodies.

The largest deposits are in the Western mine and consist of two groups of veins separated by a barren area. Most of the magnesite bodies are in the vein system consisting of comparatively short and irregular shear zones, formed after the more regular and northwest-trending system.

The western veins, known as the White Diamond-Silver group (see pls. 38, 41) include at least nine large mineralized veins and a number of smaller ones, together with mineralized branching shears. The exact number of veins is not known because some may be extensions of others, poor exposures in intervening areas preventing positive correlation. The strikes of the veins vary considerably within the quadrant north to northwest. Only the southern end of the Diamond vein strikes northeast. The other veins are roughly alined but most are somewhat curved, and some change in strike rather abruptly. Branching shear zones split from the larger veins at small acute angles without systematic direction and may even rejoin the larger veins from which they diverge. The veins converge downward, so the central veins dip steeply and the veins toward the flanks of the system dip at moderate angles toward the center of the group (see pl. 45), with the exception of the veins at the extreme limits of the area, which dip away from the central part of the group. The magnesite body in the southwest part of the area, No. 7 vein (see pl. 44), is the only deposit of this group to be located in a shear zone of the earlier northwest-trending system. Although the northern parts of the Diamond, Silver One, and Silver Two veins strike northwestward, their dips are not concordant with the dip of shear zones of the earlier system.

Mineralization in the eastern veins, known as the White Queen group, is heaviest along No. 6 vein and in the shear zones close to No. 6 vein (see pls. 46-47). The southern part of No. 6 shear zone strikes N. 25° E.; the northern part strikes N. 38° W., the strike changing fairly abruptly near the north end of the vein. The dip of No. 6 is westward at moderately steep angles. Most of the remaining magnesite bodies of this group are in shear zones branching from No. 6 vein or cut by it. Most smaller magnesite bodies of the White Queen group strike northwest and dip northeast at steep angles. On aerial photographs it is seen that the majority of them lie in the long straight shear zones of the earlier system. Angles between these shear zones and No. 6 shear zone are much greater (up to 90°) than the narrow, acute angles between the veins and branching shears in the White Diamond-Silver group (see pl. 39).

One thousand feet south of the White Queen group is the Pacific vein (see pl. 48), which strikes north and dips westward at moderately steep angles. The Pacific vein may be a continuation of the White Queen group.

Magnesite bodies in the other deposits of the Red Mountain district also are in shear zones, but the relation of these veins to structural patterns in the country rock was not studied. The three bodies of the Red Mountain mine are in one serpentinized shear zone striking northwest and dipping southwest. A parallel zone several hundred feet to the west has been but slightly mineralized (see pl. 49). The magnesite body of the Security deposit consists of several small veins in a serpentinized crush zone trending north. The Fidelity deposits consist of stockworks and nodules emplaced in a rather wide crush zone or possibly a breccia pipe.

Individual shear zones vary greatly in size and shape but have several structural features in common. All but the smaller veins have strong slickensided shear planes forming either hanging walls or footwalls, or both. Such shear planes branch in many places, at acute angles, most of the splits going into the shear zone proper, and also into the country rock. They are variable in continuity, extent, and number, as may be seen on underground maps (see pls. 42, 43). Generally the stronger walls are in the larger veins.

Although most shear zones consist mainly of serpentine, many contain segments of peridotite breccia. The serpentine is confined to the shear zone proper, and does not extend beyond hanging-wall and footwall shear planes, whereas the peridotite breccia may extend beyond the walls. The largest such breccia area is on the west, or hanging-wall side of No. 6 vein, and is 100 feet wide. Other areas containing large breccia masses are in the wedges between shear zones and their branching splits, as, for example, in the Silver One vein of the White Diamond-Silver group (see pl. 43).

All movement occurring in the shear zones during mineralization was in the plane of the zones. Only two small cross faults were mapped, one in the Ehrman vein (pl. 42), and the other near the southwest end of No. 6 vein (pl. 46); these seem to be of premineral age. Movement during mineralization followed old shear planes and also formed new ones. Lenses of massive magnesite are cut by undulating slickensided shear planes which never are plane surfaces but curve sinuously and may be strongly corrugated normal to the plunge of the slickensides. Other structures produced by movement during mineralization include breccias, mylonites, and intricate folds in previously deposited material.

Magnesite breccias are fairly common in some bodies. At some places the magnesite is cemented by the same mineral, whereas at other places it is cemented by post-magnesite minerals. This relationship shows that movement occurred in the shear zones during and after magnesite deposition (see table 4, no. 62-b).

Mylonitized magnesite (see table 4, analysis 73; and pls. 34, 36*B*, 37) consists of finely ground magnesite, magnesite breccia fragments, and small amounts of serpentine. It has a banded appearance, resulting from the serpentine content of the pink and gray layers, and forms veins from 3 inches to 3 feet thick along strong shear planes which may form either the hanging wall or the footwall. It occurs in the Diamond vein and No. 1 vein of the Western mine, and also along the main vein of the Red Mountain mine (see pl. 49).

Throughout the deposits, some narrow seminodular magnesite veins as much as a foot wide are irregularly folded. Such folds appear to be ptygmatic when seen in vertical section but are not badly contorted along the strike. The magnesite shows no sign of internal deformation and therefore must have been plastic during movement.

The distribution of minerals in the shear zones can be generalized as follows: magnesite may be found throughout a given zone, mainly as replacement bodies and to a lesser extent as fracture filling (see figs.

2-4, pl. 40), but most of the larger bodies are localized by certain premineral structures. All post-magnesite minerals are in fractures which were open at the time of their deposition. The silica-magnesium silicate minerals commonly occur in largest amounts along the shear-plane walls, but they also occur in the shear-plane branches in magnesite, in brecciated magnesite, and in serpentine. The thickness of such minerals ranges from thin films to 10 feet, although the upper limit is well above the average. Intimate and heterogeneous mixtures of these minerals resulted from shattering of the earlier silica minerals during movement in shear zones.

The larger magnesite bodies are localized within individual shear zones, and where three-dimensional data are available, it is evident that the bodies are related to the structure of the shear zones. Change of strike or dip exerts a marked influence on the limits of magnesite bodies as does the branching of major splits from the main zone.

The effect of deviation of attitude of the shear zone on the location of magnesite bodies may be shown in the following examples:

1. The large magnesite body along the entire length of No. 1 vein (see pl. 42) is located on a vein with slightly curved shape. The plunge of slickensides shows that movement was oblique across this structure.
2. The south magnesite body of the Diamond vein is located where the vein has several irregular flexures, and slickensides are oriented obliquely across the structure (see pl. 42).
3. The main magnesite body of No. 6 vein (see pl. 46) is located at a strong bend in the vein. Associated with the shear zone is a wide breccia zone extensively mineralized by stockwork and nodular magnesite. The breccia zone is limited to the immediate vicinity of the bend.
4. The magnesite bodies of No. 8, No. 9, No. 23, and White Queen veins (see pls. 46, 47) all terminate where the shear zones curve slightly.
5. The south magnesite body of the Pacific vein (see pl. 48) is located at a series of minor flexures in the shear zone.

Several magnesite bodies narrow abruptly at the junction of a main shear zone and a branching shear zone. In most veins the mineralized area is found on the side of the junction making the acute angle between the split and the main shear zone; in some, the branching shear zone is mineralized. Examples of these features include:

1. Both the south body of Silver One vein (see pl. 43), and the magnesite body of Silver One North vein, narrow sharply at branching shear zones. Here, the branching zones also are mineralized.
2. In the northern part of the Diamond vein, two shear zones branch from the main zone at depth. At higher levels, the branches parallel the main zone and form a strong footwall. The magnesite occurs as two bodies at depth and these coalesce at higher levels to form one of the largest deposits on this vein. Comparison of the underground maps (see pl. 42) with the vertical plan of ore distribution (see fig. 5) will clarify these relationships.
3. Similarly, Silver Two vein, south body (see pl. 42), the Ehrman vein body (see pl. 43), the south ore body of No. 6 vein (see pl. 46), and the north and central bodies of the Pacific vein (see pl. 48), are curtailed at the junction of branching shear zones. The Silver Two body is located on the obtuse side of the junction, an exception to the general rule.

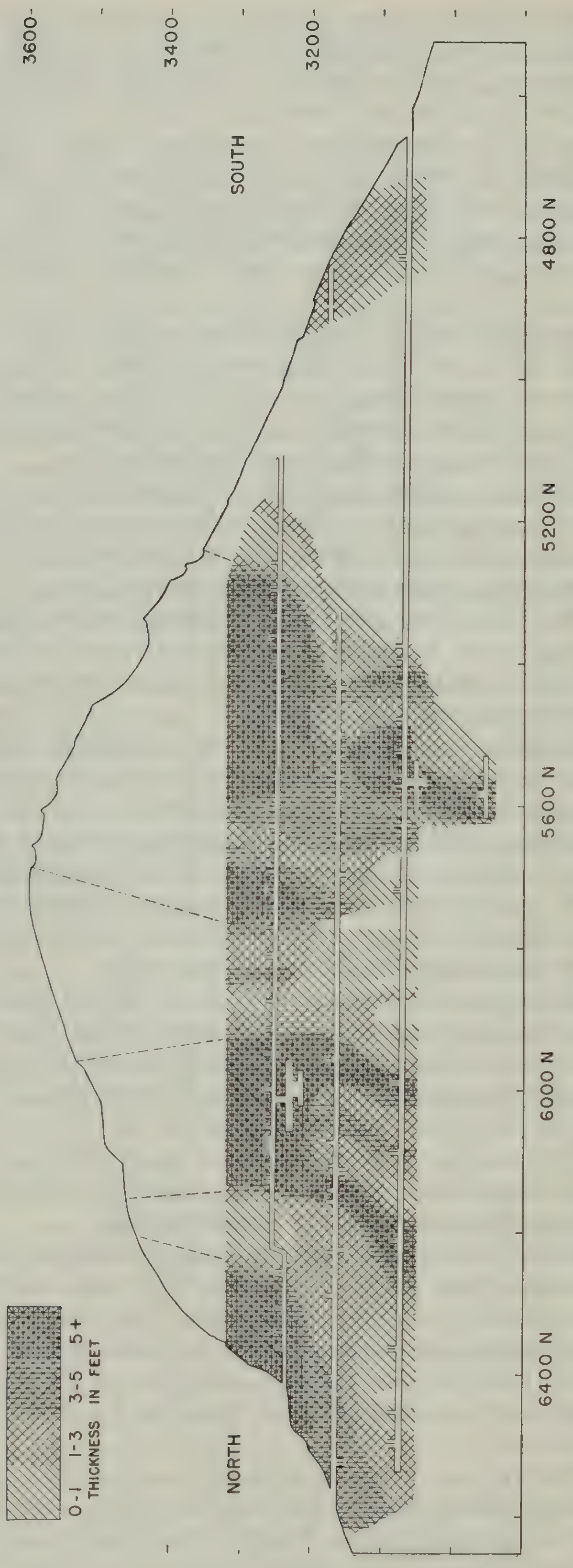

3600
3400
3200
SOUTH
NORTH
0-1 1-3 3-5 5+
THICKNESS IN FEET
4800 N
5200 N
5600 N
6000 N
6400 N

FIGURE 5. Vertical projection of the Diamond vein, Western mine. The projection is north-south and viewed from the west. Information is lacking above the 3240′ level, owing to caving of workings. The probable projection of the widest bodies upward is based on the distribution of surface workings

4. The magnesite bodies on branching shear zones and shear zones cut by No. 6 vein all owe their mineralization to the proximity of this main mineralized zone (see pls. 41, 46, 47).

The small cross faults in the Ehrman vein (pl. 42), and No. 6 vein (see pl. 46), with displacement of 5 and 15 feet respectively, occur at the end of magnesite bodies and therefore seem to be related to control of mineralization. Both faults predate the magnesite.

Within magnesite bodies, large lenses are partially bounded by shear-plane walls. On the open sides, unbounded by shear planes, the massive magnesite grades into nodular magnesite. This pattern is found in many veins, but can best be seen in the No. 1 and No. 534 veins of the White Diamond-Silver group (see pls. 42, 43). In many veins changes of width and grade of magnesite are also correlated with the local shear-plane pattern, as is well shown in the 20-scale map of Silver One vein (see pl. 40). It would appear, therefore, that magnesite deposition is related to these structures.

Individual magnesite bodies do not bottom at uniform depth, and in some instances the vertical extent of the larger bodies can be correlated with structures of the shear zones. Bases of some bodies coincide with a change of dip in the shear zone (pl. 45). The vertical plan of the Diamond vein (fig. 5) shows that the bodies do not always continue to the surface with undiminished width, and comparison of this figure with the underground maps (pl. 42) shows that the deepest bodies occur on the stronger shear structures. In the vertical plan of magnesite veins of the district (fig. 6), it may be seen that the bases of minable magnesite bodies in the White Diamond-Silver group are progressively shallower to the west, with the exception of the vein southwest of the main group.

The correlations cited clearly indicate that structures of the shear zones control the sites of magnesite deposition, both horizontally and vertically. Thus, structures controlled the flow of mineralizing solutions by affecting the relative permeability of the shear zones on a large scale, and by further channelling the solutions by means of the shear-plane structures on a small scale.[57] Movement on an irregular shear plane produces areas of lower pressure and actual openings, which permit greater flow of solutions and a greater probability of mineral deposition. Using the Diamond vein as a conspicuous example, it can be seen that movement in any direction on this most irregular surface would result in areas of greater permeability (see fig. 7). Movement in the areas between the main vein and strong branching shears probably resulted in the relative movement of the wedge-shaped block away from the point of junction, giving greater permeability to those segments of the shear zone on the acute side of the junction. In the south ore body of Silver Two vein, the relative movement of the wedge-shaped block was in the opposite direction, toward the junction of the shear zones, prying open the segment on the obtuse side of the junction and making it more permeable.

Slickensides on shear planes are not systematically oriented, other than that they rake steeply, in most places more than 45°. They may record the directions of only the later of the numerous movements in the shear zones, or possibly the slickensides in different veins were produced

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[57] Newhouse, W. H., Structural features associated with ore deposits, in Ore deposits as related to structural features, pp. 15-25, Princeton, New Jersey, Princeton Univ. Press, 1942.

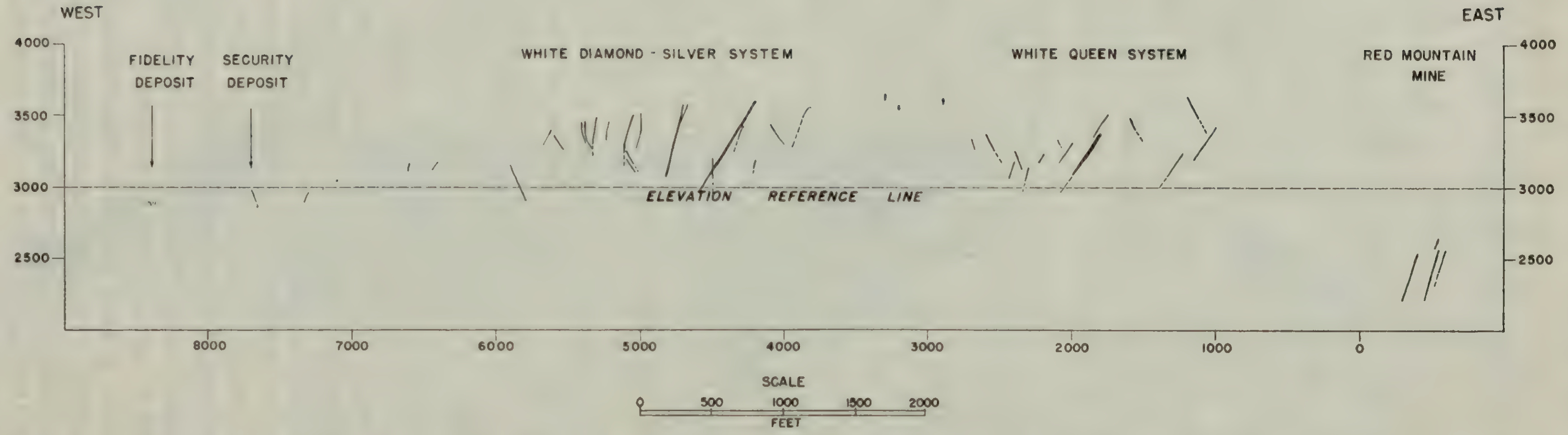
WEST
EAST
FIDELITY DEPOSIT
SECURITY DEPOSIT
WHITE DIAMOND - SILVER SYSTEM
WHITE QUEEN SYSTEM
RED MOUNTAIN MINE
ELEVATION REFERENCE LINE
4000
3500
3000
2500
8000
7000
6000
5000
4000
3000
2000
1000
0
SCALE
0
500
1000
1500
2000
FEET

FIGURE 6. Vertical projection of magnesite veins, Red Mountain district viewed from the south. The maximum known extent of the veins is shown, the top coinciding with the surface. Coordinates correspond to the Western mine coordinate system

by different periods of movement. If the slickensides throughout the veins do represent any one movement, then the adjustment between blocks was complex, but generally in the vertical or steeply oblique directions. None of the movements were of great magnitude, for the shear zones are comparatively short and some fray into the peridotite. They were sufficiently large, however, to provide the necessary permeability for the passage of the mineralizing solutions.

From this proof of the influence of structure on magnesite deposition, it follows that structure has an important role in governing the size, shape, and to some extent, the grade of the magnesite bodies.

In vertical extent few bodies continue below an elevation of 3,000 feet, with the outstanding exception of the Red Mountain mine deposits bottoming at 2,200 feet (see fig. 6 and table 7). The bases of most minable bodies have been found, although unminable magnesite undoubtedly continues to greater depths. Because magnesite is a low-priced commodity, operators have not explored at depth; to this extent, the lower limit of minable bodies has been governed by economic considerations.

The vertical projection shows that the majority of veins are in a zone roughly paralleling the surface, an indication that a general zone of deposition prevailed. It is not known at what depth deposition occurred, but the compact nature of the deposits indicates that it was not related to the present surface, for should this have been so, the numerous movements could have opened up innumerable channels and the country rock possibly would have contained extensive stockwork deposits.

The areal distribution of veins (see pls. 38, 40) indicates two main centers of mineralization in the Western mine area, with minor mineralization west of the White Diamond-Silver group and north of the White Queen group. Mineralization of the Pacific vein may be related to that of the White Queen area. The Red Mountain, the Security, and the Fidelity deposits are independent centers of mineralization.

The mineralization is related to the large shear zones produced by the second period of deformation. All such shear zones are not mineralized. For example, although several large zones cut the area between the White Diamond-Silver and the White Queen areas, no mineralization of any importance is found in such zones. Relating this to the fact that the northwest-trending shear zones are only mineralized near the large centers of mineralization, it becomes evident that deposition is controlled by select shear zones of the second system. No. 6 vein is obviously the master structure of the White Queen group. The veins in the White Diamond-Silver group are more equal in size, but the Diamond vein seems to have been the strongest structure.

The second system of shear zones seems to have been produced by tensional stresses acting horizontally, in a general east-west direction. The convergence of veins downward, the rude parallelism of the veins, the abrupt changes in strike, the numerous branching shear zones diverging at small angles, all indicate that horizontal tensional stresses produced the shear zones of the White Diamond-Silver group. The abrupt change in strike and the large hanging-wall breccia of No. 6 vein of the White Queen group is strong indication that the structure is a normal fault. That the location of magnesite deposition is not primarily related to location of serpentine bodies can be shown by the scarcity of magnesite deposits in serpentinized dunite areas (see pl. 38).

Similar relations of magnesite bodies to vein structures exist in other deposits of California. Eight deposits in various parts of the state were visited in 1943 by Eugene Callaghan and the writer. In all but one deposit it was evident from cursory examination that the mineralization centered in shear or crush zones. Many of the vein structures described for the deposits of Red Mountain were similar to those seen in these other districts.

Paragenesis

Subsequent to the formation of the second shear-zone system and the very minor cross faults, solutions carrying magnesium carbonate deposited magnesite in the shear zones. At least one period and possibly two periods of movement in the shear zones occurred during magnesite deposition. This movement, although small, resulted in mylonitization, shearing of some massive bodies and brecciation of others, and ptygmatic folding of narrow veins. It is not quite clear whether mylonitization was the product of an early movement in the veins or whether it was produced by the movement that caused the other types of deformation in the magnesite. The main period of deformation occurred near the end of magnesite deposition, because much brecciated magnesite was recemented by the same mineral. At the end stage of this period, some calcium in the solutions combined with magnesia, and minor amounts of dolomite were deposited. Small amounts of manganese oxides were then deposited on surfaces of magnesite bodies.

After the close of magnesite deposition, minor movements in the shear zones alternated with deposition of the silica and magnesium silicate minerals, all as fissure fillings. Additional movements occurred during the deposition of chalcedony and opal. Deweylite and sepiolite apparently were not fractured during their deposition. After the close of the silica-magnesium silicate mineral deposition, some veins were again subjected to movement, and calcite was deposited in the open fissures.

Movement in the shear zones occurred at least eight times and possibly nine times during the mineralization of this area. The amount of movement always was slight and in the plane of the veins.

Size, Shape, and Grade of Deposits

The size and shape of magnesite deposits is dependent on amounts of solutions passing through the shear zones and the structures channelling such solutions. The resulting bodies vary considerably in dimension.

Magnesite bodies of minable size range in length from 100 to 900 feet. Some veins have several ore bodies, as for example, the Diamond vein and Silver Two vein. The ore bodies of the White Diamond-Silver group generally are larger than those of the White Queen group. The larger veins of the White Diamond-Silver group all carry ore bodies at least 400 feet long, whereas, excepting the 900-foot main body of No. 6 vein, maximum length of bodies in the White Queen group is 350 feet.

The width of ore bodies is extremely variable, ranging from veinlets and thin stringers to bodies of solid magnesite 35 feet wide.[58] The width may differ considerably from point to point because of the nature of mineralization. The total width of the mineralized zone in the No. 6 vein main ore body is approximately 120 feet, including the wide stockwork

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[58] Hess, F. L., op. cit., p. 35.

Table 7. Description of magnesite bodies, Red Mountain district, California

	Vein	Location	Length	Vertical range	Strike	Dip
	WESTERN MINE					
1	Lower No. 12 vein	Extreme west side, Diamond-Silver	160′	2860′—2960′=100′	N. 12°-55° E.	40°-70° NW.
2	Middle No. 12 vein	East of lower No. 12 vein	100′	3110′—3160′=50′	Surface trend N. 55° W.	
3	Upper No. 12 vein	East of middle No. 12 vein	160′	3170′—3220′=50′	N. 3°-12° E.	74°-85° NW.
4	No. 546 vein	West side, Diamond-Silver area	Possibly 250′	3240′—3370′=130′	N. 18° W.	47° NW.
5	No. 546 north vein	North of No. 546 vein	About 220′	3275′—3390′=115′	N. 0°-18° E.	44°-58° NW.
6	No. 7 vein	Southwest side Diamond-Silver area	450′	2900′—3200′=300′	N. 40°-50° W.	60°-70° NE.
7	Silver 3 vein	West central Diamond-Silver area; east of No. 546	470′	3240′—3465′=225′	N.	Top, vertical; base, 60° E.
8	No. 534 vein	Between Silver 2 and Silver 3 veins	520′	3240′—3465′=225′	N. north end hooks east	Top, 80° E.; bottom, 55° E.
9	Silver 2 vein	Between No. 534 and Silver 1 veins	1050′	3240′—3505′=265′	South end-about N. North end-N. 45° W.	Top, 65° SW.; 80° SW. of base.
10	Silver 1 vein	Between Silver 2 and No. 1 veins	900′	3240′—3520′=280′	South end-N. 40° W. North end-N. 20° W.	Vertical to steep west dip.
11	Moffat veins	South-central Diamond-Silver area	320′	3090′—3260′=270′	Northeast vein-N. 40° W. Southwest vein-N. 30° W.	50°-68° NE. 40°-50° NE.
12	No. 1 vein	Between Silver 1 and Diamond vein	750′	3060′—3570′=510′	N., bowed east at ends	60°-75° W.
13	Little Myrsky vein	East split of No. 1 vein	About 400′	3450′—3575′=125′	Curved, concave to west	50°-60° W.
14	No. 55 vein	North end of No. 1 vein	250′	3160′—3380′=220′	N. 20°-40° W.	75° SW.
14a	East O'Shaunnessy vein	East of No. 55 vein	130′	3340′—3410′=70′	N. 40° W.	50°-80° SW.
15	Diamond vein	East side, Diamond-Silver area; east of No. 1 vein	1800′	2950′—3610′=660′	South end N. 45° E. North end N. 45° W.	45°-60° W.
16	North Drift vein	Northeast of Diamond vein	Probably 300′	3230′—3430′=200′	N. 50°-60° W.	74° SW.
17	Ehrman vein	East of Diamond vein	400′	3290′—3460′=170′	N. south end hooks east	45° E.
18	Roadcut vein	South of Ehrman vein	110′	3140′—3200′=60′	N. 40° W. ±	60° SW?
19	No. 5 vein	East side, Diamond-Silver area	300′	3240′—3580′=340′	N. 70° W. ±	24°-48° SW.
20	North prospects	Northeast of Diamond-Silver area; north, northwest of White Queen	150′-280′	3530′—3660′=130′	3 veins N. 20° W.; N. 60° W.; N. 70° W.	?
21	White Queen vein	Northeast corner White Queen	250′	3340′—3510′=170′	N. 18° W.	68° SW.
22	No. 6 vein	Central White Queen area	1700′	3055′—3390′=335′	North end-N. 35° W. South end-N. 20° E.	50°-60° W.
23	No. 27 vein	West side White Queen area	Possibly 150′	3250′—3320′=70′	N.	60°-70° E.?
24	No. 9 vein	West White Queen between No. 27 and No. 6	280′	3280′—3380′=100′	N. 15° W. south end hooks east	60° E. ±
25	No. 9 south vein	West central White Queen area	360′	3135′—3250′=115′	N. 25° W.	60° NE.
26	No. 15 vein	Central White Queen area	380′	3230′—3340′=110′	N. 55° W.	60°-75° NE.
27	No. 6 split	Central White Queen area	130′	3170′—3320′=150′	N.	35°-66° W.
28	No. 8 vein	East White Queen area	330′	3230′—3495′=265′	Bowed south end N. 85° W.; north end N. 65° W.	Top, 50° NE.; base, 65° NE.
29	No. 16 vein	Easternmost White Queen area	440′	3340′—3625′=285′	N. 50°-55° W.	50° NE.
30	No. 23 vein	Southernmost White Queen area	300′	3035′—3140′=105′	Bowed south end N. 5° E.; north end N. 25° W.	70°-80° W.
31	Pacific vein	South of White Queen area	900′	3050′—3425′=375′	N. 20° W. ±	30°-50° W.

Table 7. Description of magnesite bodies, Red Mountain district, California—Continued.

Vein	Location	Length	Vertical range	Strike	Dip
RED MT. MINE					
Main vein	Northeast of White Queen area	870′	2200′—2570′=370′	Mostly N. 18° W. South end=N. 30° W.	Mostly 70° W.
Secondary vein	West of main vein	?		Generally parallel to main vein	
SECURITY DEPOSIT					
	North of No. 12 area Diamond-Silver	200′ minimum	2890′—2980′=90′ minimum	About N.	78°-90° E.
FIDELITY DEPOSIT					
	Northwest of Security deposit	100′ minimum	At 2900′ elevation	Veins strike from N. 12° E. to N. 27° W.	74° W. to 76° E.

	Vein	Number of shoots	Description of shoots	No.
	WESTERN MINE			
1	Lower No. 12 vein	One	60′ long, 3′ maximum width. Ore nodular to massive. Walls strong	1
2	Middle No. 12 vein	One	Surface exposures 100′ long, up to 5½′ wide. Pinches 50′ below	2
3	Upper No. 12 vein	One	70′ exposed in drift, up to 5′ wide. Most ore low grade, some high grade	3
4	No. 546 vein	One	120′ long, 6′ wide at surface; pinches and shortens downward. Vertical pitch	4
5	No. 546 North vein	One	200′ long, possible 6′ wide at surface; pinches downward. Strong footwall	5
6	No. 7 vein	One	450′ long, 13′ solid ore maximum width. Ore nodular, medium to high grade. Strong walls	6
7	Silver 3 vein	One	470′ long, 175′ high, 30′ maximum width. Ore medium to high grade. Mostly nodular	7
8	No. 534 vein	One	500′ long, 15′ maximum width. Ore medium to high grade, many massive lenses. Good hanging wall	8
9	Silver 2 vein	Two, partially coalesced	South shoot—500′ long, 250′ vertical extent, 15′ maximum solid ore. Ore medium to high grade North shoot—220′ long, 90′ vertical extent, 10′ maximum width solid ore. Ore medium to high grade.	9
10	Silver 1 vein	Two, plus two splits, ore of which is heavily mineralized	South shoot—370′ long, 170′ vertical extent, 30′ maximum width, medium to high grade. Mostly nodular North shoot—300′ long, 140′ high, 15′ maximum width, all nodular, low to medium grade.	10
11	Moffat veins	One One	Northeast vein—320′ long, 270′ high, 5′ maximum width, nodular ore; shoot 100′ long Southwest vein—320′ long, 120′ high, 8′ maximum width. Shoot 200′ long. Ore nodular, low to medium grade.	11
12	No. 1 vein	One	750′ long, 17′ maximum width. Nodular to massive ore. Walls branching discontinuous	12
13	Little Myrsky vein	One	300′ long, 5′ maximum width. Nodular ore, low to medium grade. Walls branchings, discontinuous	13
14	No. 55 vein		No ore body—slightly mineralized along 250′ horizontally; up to 4′ width nodular ore	14
14a	East O'Shaunnessy vein	One	Shoot 100′ long, up to 2′ wide on surface; wider at depth but contains low grade nodular. Magnesite	14a
15	Diamond vein	Two main shoots, each with three roots or pendants Several mineralized splits	South shoot—600′ long, 660′ high, 20′ maximum width. Ore nodulor to massive, medium to high grade North shoot—1000′ long, 470′ high, 30′ maximum width. Ore nodular to massive, medium to high grade.	15
16	North drift vein	One?	Probably nodular ore. Surface cuts indicate shoot to be about 300′ long	16
17	Ehrman vein	One, plus one split	310′ long, 15′ maximum width. Ore mostly nodular, low to high grade. Split with small ore body	17
18	Roadcut vein	One	Nodular ore in 4½′ shear zone. May be extension of southeast split of Diamond vein	18
19	No. 5 vein	One, possible two veins	Nodular ore, poor below surface exposures. May be split of North end Diamond vein	19

20	North prospects	One per vein	Surface croppings only. Information meager	20
21	White Queen vein	One	230′ long, 6′ maximum width at 3340′ level. Ore nodular to solid, medium to high grade	21
22	No. 6 vein	Three	Main (N) shoot—900′ long, 250′ vertical extent of mining; 35′ solid magnesite, 100′ stockwork—maximum widths Middle shoot—80′ long, 60′ high, possibly 10′ wide. South shoot—200′ long, 135′ high, 16′ maximum width. Ore nodular, medium to high grade.	22
23	No. 27 vein	One?	Surface croppings indicate shoot possibly 150′ long and up to 4′ wide	23
24	No. 9 vein	One	210′ long at drift, 150′ at surface; 8′ maximum width. Ore nodular, medium to high grade	24
25	No. 9 south vein	One	Probably 350′ long, up to 20′ wide. Worked out and inaccessible.	25
26	No. 15 vein	One	About 280′ long, 60′ high, up to 4′ wide. Worked out and inaccessible.	26
27	No. 6 split	One	Completely pinched at 3170′. Vein frays northward on 3170′ level	27
28	No. 8 vein	One	220′ long, at least 100′ high, up to 7½′ wide. Nodular, few solid lenses	28
29	No. 16 vein	One	100′ long, possibly 170′ high, 5 maximum width. Ore mostly medium grade nodular	29
30	No. 23 vein	One	200′ long, 105′ vertical extent of mining, 10′ maximum width. Ore mostly nodular, medium to high grade	30
31	Pacific vein	Three, and one main split	North shoot—250′ long, mined possibly 160′ vertically; 8′ maximum width. Slightly mineralized. Split at north end. Ore nodular. Middle shoot—100′ long, mined 90′ vertically; 5′ maximum width. Ore nodular, medium grade. South shoot—200′ long, 250′ high, up to 17′ wide. Nodular ore, medium grade.	31

RED MT. MINE		
Main vein	Three and one mineralized split	Main (N) shoot—possibly 280′ long, 350′ high, up to 60′ wide. Ore mainly nodular, low to high grade. Middle shoot—possibly 90′ long, mined 170′ vertically. Inaccessible—width and grade of ore unknown. South shoot—possibly 170′ long at surface, much shorter at depth; mined 170′ vertically; ore up to 5′ wide in surface cut.
Secondary vein	Scattered exposures. One small shoot near south end	South shoot—Exploratory cut and cross-cut indicates 4′ shear zone with less than 1′ of magnesite.
SECURITY DEPOSIT		
	One	Ore body consists of 2 veins totalling 4′ maximum width of magnesite in 30′ shear and crush zone. Ore is low to medium grade nodular.
FIDELITY DEPOSIT		
	One mineralized crushed zone	Surface exposures of crush zone show 100′ by 100′ area of veins, nodules and stockwork deposits.

zone in the hanging wall (see pl. 46). The larger ore bodies of the White Diamond-Silver group carry as much as 15 feet of solid magnesite and wider zones of nodular magnesite. One short segment of Silver One vein, south ore body, is 30 feet wide; at a branching shear zone in the northern part of the Diamond vein, the mineralized zone is 40 feet wide (see pl. 42). Generally, most ore bodies in this group are less than 10 feet wide, and the bodies in the White Queen group, except No. 6, are narrower.

In 1944, the required width for profitable mining was 2½ feet of solid magnesite; where the magnesite occurs as disseminated nodules, wider bodies were necessary. With the exception of one small block mined in the Diamond vein, the veins operated in 1944 were at least 5 feet in width.

The known vertical extent of bodies ranges from 50 feet in the No. 12 vein area to 660 feet (860 feet down dip) in the Diamond vein. No. 1 vein has been mined 510 feet from the lowest level to the surface, but most of the other ore bodies have been mined from 100 to 300 feet vertically. Most operations have reached the bottom of commercial ore, but there are several exceptions (see table 7).

The chemical composition of mined magnesite consists on the average of 94 to 95 percent magnesia, approximately 2 percent lime and 3 percent insoluble material (mainly silica). Even when some ore is high in lime there is enough low-lime material to permit blending, and thus the lime is never a problem. Serpentine in the ore, on the other hand, can get close to the critical limit, and this type of ore must be watched by operators to insure a standard product.

The average analyses of 1943 shipments are given in table 8. Comparison with analyses 51-b, 56-c, 59-b, and 65-a, table 4, shows the excess of silica in ore as contrasted with hand specimens. The 3 percent silica is equivalent to more than 6 percent serpentine.

Table 8. Analyses of ore shipments, average for the year 1943 [1]

Crude, select grade—average of 34 shipments	
$CaCO_3$	2.13 percent
$MgCO_3$	94.96 percent
SiO_2, Fe_2O_3	2.94 percent
Deadburned, converted to crude—average of 58 shipments	
$CaCO_3$	2.22 percent
$MgCO_3$	94.32 percent
SiO_2, R_2O_3	3.46 percent

[1] Through the courtesy of the Westvaco Chlorine Products Corporation, New York, N. Y.

Reserves

The specific gravity of cryptocrystalline magnesite has a considerable range, but most material is between 2.9 and 3.0. The value of 2.91 is arbitrarily used to furnish the conservative tonnage factor of 11 cubic feet of magnesite per ton. During mining operations, only about 80 percent of ore in place is recovered, so the figures that follow are subject to a reduction of 20 percent.

Ore bodies can be reliably measured only in underground workings and surface cuts. Reserves are classified as measured, indicated, and inferred. Measured ore is calculated from data obtained from the backs of stopes and drifts. Measurements are projected from 40 to 50 feet upward because most ore is consistent in that direction, whereas such data are projected but 20 feet downward. Indicated ore is calculated by projection of the same data from above the measured block to the surface; downward, the data are projected various distances, depending on geologic indications. Inferred ore is calculated on the basis of geologic indication only. No attempt has been made to estimate reserves in blocks and pillars now inaccessible, because reports vary widely and many of them are unreliable.

On the surface, reserves in open cuts are classified as measured. Reserves of veins exposed only in discontinuous outcrops and trenches are classified as indicated and inferred.

The total reserves of the Western mine, the Red Mountain mine, the Security and the Fidelity deposits are 82,600 short tons measured ore, 47,900 tons indicated ore, and 48,700 tons inferred ore, a total of 179,200 short tons. By far the biggest part is in the Western mine. These figures have been compiled for the parts of veins in the minable range, and do not include potential bodies at depth.

Origin

The writer believes that the cryptocrystalline magnesite deposits at Red Mountain were formed by precipitation from hypogene solutions, which probably derived their magnesium content from reaction with magnesium-rich ultramafic rocks. Field and laboratory evidence is cited against the views that magnesite was formed by metasomatic replacement of peridotite and that the deposition of magnesite was from supergene solutions. The evidence and arguments follow in detail.

The action of carbonate waters on magnesium silicate minerals forms magnesite as one product, according to Van Hise:[59]

$$1.\ 3Mg_3FeSi_2O_8 + 3CO_2 + 4H_2O + O \longrightarrow 2H_4Mg_3Si_2O_9 + Fe_3O_4 + 3MgCO_3 + 2SiO_2 + k,$$

where k represents heat. F. L. Hess[60] noted the absence of magnetite in magnesite and suggested that sufficient water is present to hydrate the iron. Hess states that enstatite likewise could be altered to magnesite.

Another reaction producing magnesite is that between serpentine and carbonate waters, given by Waldemar Lindgren[61] as the reaction between serpentine and carbon dioxide:

$$2.\ H_4Mg_3Si_2O_9 + 3CO_2 \longrightarrow 3MgCO_3 + 2SiO_2 + 2H_2O.$$

However, magnesium, like calcium, is carried in solution as a bicarbonate, and the reaction might better be written as:

$$3.\ H_4Mg_3Si_2O_9 + 6H_2CO_3 \longrightarrow 3Mg^{++} + 6HCO_3^- + 2SiO_2 + 5H_2O.$$

Solutions carrying magnesium can alter peridotite, as was observed in the field. However, the Van Hiss formula (1) is invalid because it requires excess oxygen, not normally a constituent of carbonate waters.

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[59] Op. cit., p. 309.

[60] Op. cit., p. 18.

[61] Lindgren, Waldemar, Mineral deposits, 4th ed., p. 388, New York, McGraw-Hill Book Company, Inc., 1933.

It would seem to the writer that serpentine is the more logical source because only carbonate waters are required to take magnesium into solution. The field evidence suggests that serpentine is more susceptible to attack by carbonate waters than an anhydrous silicate mineral such as olivine would be. It is concluded that reaction (3) is the most acceptable formula for the derivation of magnesium. This reaction also furnishes a source for the silica deposited as chalcedony and opal after the deposition of magnesite.

Assuming that the magnesium required for the formation of magnesite and the associated minerals was derived from serpentine, the alteration did not occur in place as suggested by earlier workers. There is no sign of alteration of the serpentine other than oxidation of magnetite. The minerals were not deposited simultaneously, but in distinct sequence. Furthermore, the ratio of magnesite to the silica and magnesium silicate minerals is not constant and only by chance equal to what would be expected from simple alteration of serpentine in place. Finally, consideration of relative volumes of serpentine and the products of the reaction shows that a substantial decrease is effected by the reactions; this is not reflected in the deposits, which are compact. F. L. Hess [62] realized this difficulty, but failed to explain it in terms of alteration in place by meteoric waters. It thus seems likely that the magnesite was formed by deposition from solutions rich in magnesium and bicarbonate ions. The source of these solutions remains to be demonstrated.

Theories on the origin of cryptocrystalline magnesite fall into two main groups: deposition by supergene waters, and deposition by hypogene waters. Since it has been shown that the magnesite was not derived from the immediately adjacent serpentine, it must have been derived from magnesium silicate minerals either above or below the present observable zone of deposition. In terms of this qualification, the theories may be stated as follows: (1) Supergene waters containing carbon dioxide dissolved from the atmosphere react with serpentine, taking magnesium into solution as the bicarbonate; the mineralized waters percolate downward and deposit magnesite wherever the solutions become supersaturated; (2) hypogene waters, charged with carbon dioxide from magmatic sources, dissolve magnesium from serpentine, and carry the magnesium bicarbonate upward to the zone where supersaturation, possibly by loss of carbon dioxide, causes deposition.

To decide between these alternates, the field and laboratory evidence is reviewed, and additional geochemical data on the nature of magnesium-bearing solutions are discussed.

The relation of the deposits to the surface prevailing at the time of mineralization is of importance, because one line of evidence emphasized by those advocating the supergene origin of magnesite is that the deposits are close to the surface. But this hypothesis also requires that the magnesium silicate rocks at the surface be leached, and that the terrane be suitable for the accumulation and deep penetration of meteoric waters. Neither of these conditions is met at Red Mountain. Some of the largest deposits are along the western ridge crest of Red Mountain, where there is a minimum accumulation of meteoric water. It also is noteworthy that some ore bodies are not widest at the surface (see fig 5). The hypogene origin of magnesite requires that the solutions be under high carbon dioxide pressure. This condition likewise is not met, because the country rock at present is permeable, and would have been even more so during the periods of movement which occurred during mineralization. It is concluded that the present surface is not the same as that which prevailed during mineralization, regardless of which theory of origin is accepted.

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[62] Op. cit., p. 29.

The present surface position of the deposits therefore cannot be used as evidence to determine the origin of the magnesite. The same arguments used above show that the relief of the intrusive body, 1,100 feet on the south side and 1,900 feet on Del Puerto Canyon side, must be the product of erosion following the deposition of magnesite. Although no estimate can be made of the thickness of cover removed since mineralization, it is clear that the deeper the post-magnesite erosion cut, the greater is the possibility that the deposits were of hypogene origin.

The nodular structure of cryptocrystalline magnesite has been cited as proof of its supergene origin by Ph. Kraft.[63] He stated that this structure is colloidal and that colloidal suspensions are carried only by supergene waters. It has since been suggested by G. T. Faust and Eugene Callaghan [64] that magnesite with similar structure can be deposited from hypogene solutions, which were concentrated or possibly gelatinous.

E. Clar [65] also considered the genesis of magnesite on the basis of its internal structure. He wrote that magnesite of hypogene origin was deposited as nesquehonite ($MgCO_3.3H_2O$), and later dehydrated to form magnesite. He noted radial structure in magnesite nodules and concluded that this represented the original structure of the aggregate prior to its desiccation. At Red Mountain, magnesite nodules have concentric structure rather than radiating structure. Further, contacts between magnesite and serpentine are tight, so shrinkage through dehydration could not have occurred after deposition of the magnesite. It is concluded that magnesite at Red Mountain was deposited as such and has not altered from nesquehonite.

Ph. Kraft [66] without benefit of spectrographic analysis, wrote that the extreme purity of magnesite favored supergene origin. Spectrographic analysis of Red Mountain magnesite shows it contains minor amounts of silicon, iron, tin, and manganese, and traces of sodium, potassium, borax, copper, lead, bismuth, aluminum, and barium. Of these, tin and bismuth are considered to be hypogene elements, and their presence is strong evidence favoring the hypogene origin of the magnesite.

Concerning the effect of structural control on magnesite deposition, F. L. Hess [67] stated that magnesite was deposited in the shear zones because they were the channels of deepest ground-water penetration. These shear zones could also have been the most permeable channels for ascending waters. The relation of magnesite to the shear-plane pattern is better proof of origin. The shear-plane walls of many massive magnesite lenses clearly mark the lateral limits of mineralization. A more uniform distribution of magnesite would be expected if the magnesite were deposited from supergene waters, because the whole terrane should have been approximately equally saturated and under about the same pressure from the hydrostatic head. It would seem that hypogene waters were the only ones that could have deposited magnesite with the distribution observed in this district.

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[63] Kraft, Ph., Ueber die Genetische Beziehungen des dichten Magnesite zu den Mineralen der Nickelsilicatgruppe: Preuss. geol. Landesanstalt. Herausg., vol. 20, pp. 1-115, 1915.

[64] Op. cit., p. 51.

[65] Op. cit., pp. 97-102.

[66] Op. cit.

[67] Op. cit., p. 20.

Considering the entire district, only five groups of shear zones were centers of mineralization, even though shear zones are numerous throughout the ultramafic intrusive body. Moreover, the largest serpentine areas in the district, the dunite bodies, contain little magnesite. This unequal areal distribution of magnesite in serpentine is further evidence that the deposits were derived from ascending solutions.

The sequence of mineralization, starting with magnesium carbonate minerals, changing to silica and then magnesium silicate minerals, and ending with calcium carbonate, indicates major changes in the composition of the mineralizing solutions. Such changes are far more likely in hypogene solutions, because the composition can change at the source, and because higher temperatures and pressures can produce accelerated reactions as the solutions migrate upward and meet different physical-chemical conditions.

The last field evidence to be considered is the composition of the spring waters and the material deposited from them. The waters originating in the ultramafic rocks are weak magnesium bicarbonate solutions, whose calcium content is only about 2 percent of their magnesium content (see table 6). Nevertheless, aragonite containing 5 percent or less magnesia is deposited from these waters. These data indicate that ground water, containing carbon dioxide dissolved from the atmosphere, can pick up magnesia from the ultramafic rocks and from magnesite, but does not readily deposit magnesium-bearing minerals. Indeed, G. T. Faust and Eugene Callaghan [68] state that such waters would deposit hydrous magnesium carbonate minerals rather than magnesite. Although L. A. Palmer [69] wrote that magnesite was deposited by supergene waters in open fissures at the Western mine, his descriptions and photographs lead this writer to the opinion that he found a hydrous magnesium carbonate mineral.

From the field evidence, as presented in the preceding pages, it is concluded that the magnesite deposits at Red Mountain are of hypogene origin. Evidence obtained from laboratory data on the physical chemistry of magnesium bicarbonate solutions will next be considered.

Faust and Callaghan [70] discussing the physical chemistry of the hypogene magnesite deposits at Currant Creek, Nevada, point out that the ascending hydrothermal solutions charged with carbon dioxide under pressure were probably acid, and that with the escape of carbon dioxide they became alkaline. When the magnesite was precipitated, the pressure of carbon dioxide was about 1 atmosphere and the depositing solutions were alkaline. The temperatures at which this occurred are in the epithermal range. The cryptocrystalline magnesite formed from solutions which may have been concentrated—possibly gelatinous. In comparison with the hydrothermal solutions, ground waters of the Currant Creek area have an average pH of 7.8 and a carbon dioxide pressure of 0.00032 atmosphere.

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[68] Op. cit., p. 70.
[69] Op. cit.
[70] Op. cit.

Ph. Kraft[71] recognized that magnesite is deposited from solutions containing carbon dioxide under pressure, but argued that this could be produced by descent of meteoric waters. While it is true that the hydrostatic head produces greater total pressures at depth, it is difficult to explain how the very low pressure of carbon dioxide in ground water could be greatly augmented. The present writer believes an external source of carbon dioxide is required to produce the necessary pressure, and therefore the solutions must have been hypogene.

The requirement of solutions containing carbon dioxide under pressure provides a mechanism to explain the comparatively even base level of the magnesite deposits. As the solutions rose to the surface, the confining pressures dropped, excess carbon dioxide escaped[72] and the magnesite was deposited in a zone approximately parallel to the surface existing at the time of mineralization. Undoubtedly the drop in carbon-dioxide pressure was facilitated by the open spaces in the breccia zones now filled with magnesite stockworks. Within the zone of deposition, structures in the shear zones modify the base level of deposition.

Physical-chemical relationships indicate, then, that the magnesite is an epithermal mineral, which confirms the tentative conclusion from field evidence that erosion is responsible for the present near-surface position of the deposits. The problem still remains as to the maximum depth of magnesite bodies at Red Mountain. Although the majority of the veins are thin at an elevation of 3,000 feet, workable magnesite bodies occur at 2,200 feet in the Red Mountain mine. It is the writer's opinion that the magnesite bodies continue below 3,000 feet in the Western mine area. However, the deposition of large bodies of magnesite is dependent on favorable structures in the shear zones. In the observable range the shear zones are irregular, and it is to be expected that the irregularities persist in depth. Therefore, predictions of the sites of mineral bodies at depth on the basis of present field observations would be tenuous.

The deposition of dolomite at the end of magnesite formation indicates that the solutions became saturated with respect to dolomite at the end of the carbonate stage of deposition. The silica, deposited as chalcedony and opal, was probably derived from the decomposition of serpentine. The magnesium and silicon required for the formation of the hydrated magnesium silicate minerals undoubtedly were taken into solution from the country rock. The composition of the solutions during the deposition of the silica and magnesium silicates is not known. However, G. T. Faust and Eugene Callaghan,[73] in describing deweylite at Currant Creek, Nevada, state that this mineral was deposited from alkaline solutions containing carbon dioxide. Temperatures of the solutions and the pressure of carbon dioxide were lower then than during the deposition of magnesite. The last mineral deposited at Red Mountain was calcite. The solutions which deposited it probably were cool at that stage because no reaction took place between calcite and the previously deposited magnesite.

Reference to studies made by others on the origin of cryptocrystalline magnesite has largely been omitted in the discussion of the deposits at Red Mountain. With the object of presenting the background of the problem for use in future investigations, the American and European literature on this subject is herewith briefly reviewed.

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[71] Op. cit.
[72] Faust and Callaghan, op. cit., pp. 54-55.
[73] Op. cit., pp. 64-68.

The supergene theory of cryptocrystalline magnesite origin was first proposed by G. Bischoff in 1847, according to K. A. Redlich,[74] and this view was uncontested until 1900. K. A. Redlich [75] agreed with the supergene theory but later changed his stand. A. Grannig [76] accepted the theory with reservations. F. Beyschlag and P. Krusch [77] concluded that magnesite was associated with surface weathering in the central European deposits, and that it therefore was supergene. A. L. Hall [78] thought that South African magnesite was supergene because the necessary volume increases prevented its formation at depth. L. von zur Mühlen [79] came to the same conclusion because serpentine inclusions in magnesite appeared to have been altered by solutions depositing magnesite. P. Krusch,[80] W. Schörnstein,[81] C. L. Sagui,[82] and A. Ignatieff,[83] all studying the European deposits, also stated that magnesite was supergene, but they did not add further evidence to support their conclusions. Papers by F. L. Hess,[84] Ph. Kraft,[85] L. A. Palmer,[86] and the U. S. Bureau of Mines,[87] have already been mentioned.

T. H. Holland,[88] working in India, was the first to suggest that cryptocrystalline magnesite was hypogene. He observed the association of hydrothermal quartz containing abundant carbon-dioxide inclusions with magnesite deposits, and concluded that the magnesite was derived from hydrothermal waters. G. D'Archiardi,[89] studying the Italian occurrences, noted the localization of magnesite veins, and found that nearby hot springs contained 5 percent magnesium bicarbonate. K. A. Redlich [90] reversed his former opinion after studying the laboratory data on bicarbonate solutions obtained by H. Leitmeier,[91] and Leitmeier [92] correlated his laboratory studies with observations of some European deposits. He noted the limited distribution of magnesite veins, the lack of contemporaneous deposition of magnesite, and the presence of nearby hot springs. J. Hogg [93] described localization of large magnesite bodies by irregularities in the shear zones of the deposits in Greece, but apparently did not realize the significance of these data. L. Finck [94] approached the problem of the source of solutions of the central European deposits. He concluded that the solutions carrying carbon dioxide were furnished by granite-syenite intrusions cutting the ultrabasic rocks. He also stated that magnesite does not pinch at depth, but this was questioned by later students. H. C. Boydell [95] carefully described the deposits in Greece and demonstrated that most of the magnesite replaces serpentine. He also noted the close association of magnesite bodies with shear zones and concluded that supergene waters could not have produced these deposits.

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[74] Redlich, K. A., The formation and occurrence of magnesite, in Doelter's Handbuch für Mineralchemie, vol. 1, p. 244, Steinkopf Press, 1912.

[75] Redlich, K. A., Die Typen der Magnesitlagerstätten: Zeitschr. für prakt. Geol., vol. 17, pp. 300-310, 1909.

[76] Granigg, B., Ueber die Beurteilung des Wirtschaftlichen Wertes des Gel-Magnesits von Kraubath: Oesterr. Zeitschr. Bergu. Hüttenwesen, vol. 48, p. 498, 1910.

[77] Op. cit.

[78] Hall, A. L., The geology of the Barbeton gold mining district: Union South Africa Geol. Survey Mem. 9, pp. 302-309, 1918.

[79] Mühlen, L. von-zur, Ueber einen neuentstehenden Magnesitbergbau am Galgenberge bei Zobten in Schlesien: Zeitschr. prakt. Geologie, vol. 28, pp. 155-158, 1920.

[80] Krusch, P., Magnesite, in Dammer, B., and Tietze, O., Die Nutzbaren Mineralien, pp. 480-503, Stuttgart, 1927.

[81] Schörnstein, W., Die Rölle Kolloider Vorgänge bei der Erz u. Mineralbildung, insbesondere auf der Lagerstätten der hydrosilikatischen Nickelerze: Abh. z. prakt. Geologie u. Bergwirtsch. (Halle), vol. 9, 1927.

[82] Sagui, C. L., The magnesite deposits of Euboea, Greece: Econ. Geology, vol. 24, pp. 654-657, 1929.

[83] Ignatieff, A., Magnesite deposits in Serbia: Mining Mag., vol. 42, pp. 217-221, 1930.

[84] Hess, F. L., The magnesite deposits of California: U. S. Geol. Survey Bull. 355, 67 pp., 1908.

[85] Kraft, Ph., Ueber die Genetische Beziehungen des dichten Magnesite zu den Mineralen der Nickelsilicatgruppe: Preuss. geol. Landesanstalt Herausg., vol. 20, pp. 1-115, 1915.

[86] Palmer, L. A., Magnesite mining in California: Am. Inst. Min. Met. Eng. Trans., vol. 75, pp. 743-756, 1927.

[87] Red Mountain magnesite mine, Stanislaus County, California: U. S. Bur. Mines War Minerals Rept. 105, 1943.

[88] Holland, T. H., Geology in the neighborhood of Salem, Madras Pres.: India Geol. Survey Mem., vol. 30, pp. 103-169, 1900.

[89] D'Archiardi, Giovanni, Magnesite di Castiglion-celle (Monti Livornesi): Soc. toscana sci nat., Atti, processi verbali (Pisa), vol. 22, pp. 53-55, 1913.

[90] Redlich, K. A., Die Bildung des Magnesits und sein natürliches Vorkommen: Fortschr. Mineralogie, Krist. u. Petr., vol. 4, pp. 9-42, 1914.

Several students, in describing the State Line chromite deposits in Pennsylvania and Maryland, concluded that the associated magnesite is hypogene. S. G. Gordon [96] noted magnesite 200 feet below the surface and suggested that this was improbable for supergene origin. E. B. Knopf [97] thought that hydrothermal vein quartz caused serpentinization and subsequent deposition of magnesite. E. V. Shannon [98] agreed with Gordon, and added that fractures had opened continually during mineralization.

P. A. Wagner [99] suggested that A. L. Hall was in error in assigning a supergene origin to the South African magnesite because of the limited distribution of the mineral, and O. Ampferer and W. Hammer,[100] using the same reasoning, said Balkan magnesite was hypogene. J. R. Thoenen [101] described the deposits in Greece, and concluded magnesite was hypogene because the veins do not thin downward and because there are sharp contacts between magnesite and serpentine.

E. Clar [102] stated that the hypogene origin of magnesite is supported in the replacement of magnesite by hydrothermal dolomite. Some data resulting from his examinations with the microscope have been discussed.

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[91] Leitmeier, H., Ueber wasserhaltige Magnesiakarbonate: Min. pet. Mitt. Tsch., pet., vol. 28, pp. 481-485, 1909.

[92] Leitmeier, H., Ueber amorphen Magnesit: Montan. Rundschau, vol. 6, pp. 319-324, 1914.

[93] Hogg, James, Magnesite deposits in Euboea, Greece: Am. Inst. Min. Met. Eng. Trans., vol. 46, pp. 128-148, 1913-14.

[94] Finck, L., Die Stellung der Gabbros und Serpentine Niederschlesiens und ihre Beziehung zu den Gneissen und den Graniten: Preuss. geol. Landesanstalt Jahrb., vol. 42, pp. 825-838, 1921.

[95] Boydell, H. C., Magnesite deposits of Euboea, Greece: Econ. Geology, vol. 16, pp. 507-523, 1921.

[96] Gordon, S. G., The chromite deposits of the State Line serpentines: Acad. Nat. Sci. Philadelphia Proc., pt. 3, pp. 450-454, 1921.

[97] Knopf, E. B., Chrome ores of southeastern Pennsylvania and Maryland: U. S. Geol. Survey Bull. 725, pp. 85-89, 1922.

[98] Shannon, E. V., Magnesite and kämmererite from Low's mine, Cecil County, Maryland: Washington Acad. Sci. Jour., vol. 15, pp. 434-438, 1925.

[99] Wagner, P. A., On olivine rocks and serpentines of the Bushveld complex: Geol. Soc. South Africa Trans., vol. 26, pp. 13-30, 1923.

[100] Ampferer, O., and Hammer, W., Die basischen Intrusivmassen Westserbiens: Akad. Wiss. Wien, Denkschr., vol. 98, pt. 1, pp. 11-15, 1923.

[101] Thoenen, J. R., Notes on the genesis of Grecian magnesite: Am. Inst. Min. Met. Eng., Tech. Pub. 67, pp. 1-9, 1928.

[102] Clar, E., Mikroskopische Untersuchungen an der Magnesitlagerstätten von Kraubath in Steiermark: Zeitschr. prakt. Geologie, vol. 36, pp. 97-102, 1928.

H. von Braunmühl [103] combined the results of extensive field work in central and southeastern Europe with a thorough review of the literature. He cites much evidence to prove Finck's hypothesis that later acidic intrusions provided the solutions which carry the carbon dioxide necessary for magnesite derivation.

R. Stappenbeck [104] showed the connection between magnesite deposits, trachytic and andesitic eruptions, carbon-dioxide mineral springs, and shear zones. J. Schadler [105] noted the limitation of deposits to fault lines and the proximity of hot springs in the Bosnian occurrences. G. Hiessleitner [106] studied many Balkan and Grecian deposits. His evidence for the hypogene origin of magnesite is similar to that of Schadler. He disagreed with von Braunmühl's statement that the solutions were derived from acid intrusives, and suggested instead a source from younger volcanic rocks. He also argued against Clar's hypothesis that magnesite is deposited as a hydrate. His descriptions of the deposits include numerous features comparable to those of the deposits at Red Mountain.

Alfred Himmelbauer [107] has written a thorough review of magnesite, which includes many data on magnesium bicarbonate solutions. G. T. Faust and Eugene Callaghan [108] include more recent chemical data, in their description of the Currant Creek, Nevada, deposits. C. J. Vitaliano [109] clearly demonstrates that the magnesite is limited to fault zones in the Currant Creek district.

Age of the Deposits

The mineralization at Red Mountain is later than the faults which border the intrusive body and the various fracture systems cutting the ultramafic rocks. The border faults involve rocks of the Chico formation (Upper Cretaceous) at the east end of the intrusive body, and therefore stratigraphic and structural evidence indicates that the deposits can be no older than Upper Cretaceous. Correlation of mineral genesis with physiography shows the deposits are older than the erosion which has deeply dissected the intrusive rocks. The upper limit of the possible age cannot be stated in more positive terms. Calcareous sinter is still being deposited and is of Recent age.

Another type of mineral assemblage found in many parts of the Coast Range ultramafic intrusive and sedimentary rocks is named "silica-carbonate rock" by A. Knopf.[110] It consists of calcite, dolomite, and some magnesite and siderite, together with chalcedony, opal, and some quartz. This suite is comparable to minerals deposited at Red Mountain. N. L. Taliaferro [111] has found such material in thrust faults and relates it to Tertiary volcanism.

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[103] Braunmühl, Hermann von, Ueber der Entstehung der Lagerstätten dichten Magnesits vom Typus Kraubath: Preuss. Geol. Landesanstalt, Archiv für Lagerstättenforsch., Band 45, 87 pp., 1930.

[104] Stappenbeck, R., Die Magnesitlagerstätten von Vrutei im Westserbien: Zeitschr. prakt. Geologie, vol. 39, pp. 81-89, 1931.

[105] Schadler, Joseph, Ueber einige bosnische Magnesitvorkommen: Berg- u. hüttenm. Jahrb. Leoben, vol. 79, pp. 146-152, 1931.

[106] Hiessleitner, Gustav, Zur Lagerstättengeologie des dichten Magnesits in Griechenland und Serbien: Berg- u. hüttenm. Jahrb., vol. 82, pp. 22-41, 1934.

[107] Op. cit.

[108] Op. cit.

[109] Vitaliano, C. J., Magnesite mineral resources at the Currant Creek district, White Pine and Nye Counties, Nevada: U. S. Geol. Survey Bull. (in preparation, 1949).

[110] Knopf, Adolph, An alteration of Coast Range serpentine: Univ. California Dept. Geol. Sci. Bull., vol. 4, pp. 425-430, 1906.

[111] Taliaferro, N. L., Franciscan-Knoxville problem: Am. Assoc. Petroleum Geologists Bull., vol. 27, pp. 109-219, 1943.

H. E. Hawkes Jr.[112] describes silica-carbonate rock in a cinnabar deposit near the headwaters of Puerto Creek, only 1 mile southeast of the Pacific vein of the Western mine. This indicates that other hydrothermal solutions of probable Tertiary age were active in the area. A similar relationship exists in the New Idria district, San Benito County, California, where cinnabar deposits with silica-carbonate rock occur near magnesite deposits. Should genetic relationships exist among magnesite, silica-carbonate rock, and cinnabar, not only might they solve the problems of dating mineralization, but they might also provide a broader picture of Coast Range mineral deposition.

Brief mention should be made of the work of J. B. Perry and G. M. Kirwan [113] at the Bald Eagle magnesite mine, 20 miles south of the Red Mountain district. The authors date the deposits as post-Tertiary in age.

Western Mine

In 1943-44, production came from the following ore bodies of the Western mine: No. 7 vein stope; No. 534 vein stope; No. 1 vein, north stope; No. 1 vein, haulage stope; Silver One vein, north stope; Silver Two vein, open cut; Diamond vein, No. 44 stope; No. 9 vein stope; No. 6 vein, open cut on main body.

No. 7 and No. 9 stopes were mined out in the spring of 1944. Nodular ore was being taken from blocks remaining in surface workings of Silver Two and No. 6 veins. Of the five stopes in operation during the late spring of 1944, No. 534 stope was the only one furnishing proportionately large amounts of high-grade ore. The lower stope of No. 1 vein was being developed in the spring of 1944; it contained medium- to low-grade ore, but prospects for improvement in the overlying block were very good. No. 1 north stope had mainly medium-grade ore, and Silver One north stope produced low-grade ore. No. 44 stope on the Diamond vein furnished a small tonnage of high-grade to medium-grade ore.

Most of the data of ore bodies in the Red Mountain district is summarized in tabular form (see table 7). Additional information is included on the following pages. Numbers of veins correspond to numbers on the index map of veins (see pl. 39).

*Nos. 1, 2, and 3.** The ore bodies of No. 12 veins (see pls. 41, 44) are small and shallow. The ore is medium to low grade and carries several percent CaO. (See table 4, analysis 59-b.)

Most veins of this group dip westward and probably are structurally unrelated to the White Diamond-Silver group, although upper No. 12 vein lies on the northwestward extension of No. 7 shear zone.

No. 4. The ore shoot of No. 546 vein (see pl. 44) has been mined out; its thickness and grade of ore are unknown. Stope lines show the shoot had vertical plunge and lengthened upward. A strong footwall shear is seen in the 3,240-level drift. An outcrop 5 feet long and up to 3 feet wide occurs 80 feet north of the 546 vein surface cut and may indicate another lens on this shear zone.

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[112] Hawkes, H. E. Jr., Wells, F. G., and Wheeler, D. P. Jr., Chromite and quicksilver deposits of the Del Puerto area, Stanislaus County, California: U. S. Geol. Survey Bull. 936-D, pp. 79-110, 1942.

[113] Perry, J. B., and Kirwan, G. M., The Bald Eagle magnesite mine, California: Am. Inst. Min. Met. Eng. Trans., vol. 148, pp. 35-50, 1942.

* The numbers here assigned to magnesite veins correspond to the numbers used in table 7 and plate 39.

No. 5. The ore body of No. 546 north vein is mined out and nothing is known of its dimensions or grade. The vein dips westward, away from the White Diamond-Silver system.

No. 6. The No. 7 vein shear zone can be traced for at least 1,000 feet on the surface, but has only small showings of magnesite beyond the main body. A 450-foot extent of the vein was exposed in the backs of the working stope (see pl. 44) at the 3,030 level, of which only the northwestern 200 feet contained minable ore. Most ore was obtained from a shoot 100 feet long, consisting of nodular to massive ore. The shoot included a lens of massive magnesite 65 feet long and as much as 13 feet wide, which was bounded by a strong footwall and hanging wall. A parallel crush zone, about 120 feet to the east of No. 7 vein on the 3,060 level, is only slightly mineralized.

No. 7. The south end of Silver Three ore shoot bottoms at 3,290 feet. The base slopes upward to the north at an angle of about 18 degrees, nearly parallel to the surface. The ore zone widens abruptly so that it is as much as 30 feet wide at an elevation of 3,450 feet, the crest of the ridge. Strong shear planes bound the narrow mineralized zone below the shoot at 3,240 feet elevation, and the footwall remains strong to the surface. Only a small block of ore remains between the 3,410 level and the hill crest. Here the ore is mainly nodular and of medium grade.

No. 8. The main ore shoot of No. 534 vein (see pls. 42, 43) has vertical plunge. The footwall is strong, and lenses of solid magnesite occur along it where small shears branch into the shear zone. The ore is of high grade, and the stope was the best operation in the Western mine during 1944. The shoot has been stoped from the 3,240 level to the 3,360 level.

No. 9. The ore body of Silver Two vein (see pls. 42, 43, 44) is composed of two partly coalesced shoots. The south shoot, the larger of the two, is completely mined out above the 3,240 level except for small blocks near the surface. Only one exploratory drift has been driven on the north shoot, at an elevation of 3,400 feet. The two shoots are coalesced at an elevation of about 3,350 feet and where the vein abruptly changes in strike. Neither shoot is bottomed at the lowest level driven on the body. At the 3,240 level, the south shoot carried 4 feet of solid magnesite in a 10-foot wide mineralized zone. In the 3,400-level drift, the north shoot carries as much at 10 feet of massive magnesite.

No. 10. The two ore bodies on Silver One vein (see pls. 42, 43) are separated by a barren zone which coincides with a change of strike in the vein. The south body, now nearly completely mined out, was one of the largest in the White Diamond-Silver group, having a width of as much as 30 feet. The ore was medium to high grade. The north body, now being mined, contains a 6-foot width of low- to medium-grade ore. Both shoots are accompanied by smaller bodies in branching shear zones.

No. 11. Two nearly parallel veins, together with splits, comprise the Moffat veins, which may be on a southward extension of either No. 534 vein or Silver Three vein. Magnesite veins are thin in the lower drifts but widen considerably toward the surface. The ore bodies are mined out.

No. 12. No. 1 vein (see pls. 42, 43) carries the third largest ore body in the district. A continuous body about 750 feet long and as much as 17 feet wide has been exposed over a vertical extent of 510 feet. Most of the ore has been mined, but blocks remain between: (1) 3,060 and 3,160 levels for the entire length of the ore body; (2) 3,300 and 3,410 levels at the north end of the vein; (3) 3,450 level and the surface south of the ridge crest. The grade of ore is variable, with good bodies of massive ore scattered through lower-grade material. As in the case of the massive lenses found in No. 534 vein, most lenses are bounded by a main shear plane and a branching shear plane. The location of the body as a whole is favored by the arcuate shape of the vein, along which movement has been oblique. The vein runs into No. 55 vein at its northern end.

No. 13. The Little Myrsky vein (see pl. 43) is an arcuate split of No. 1 vein. The north end has been mined nearly to the surface. Exposures in the now dormant stope indicate that the ore was of medium to low grade.

No. 14. No. 55 vein (see pls. 42, 43) is the obliquely crosscutting vein terminating No. 1 vein at its northern end. Two drifts, one 220 feet above the other, failed to find minable magnesite.

No. 15. The ore bodies of the Diamond vein (see pl. 42, fig. 5) and their relations to structures have been described. Most of the large bodies of high-grade ore have been mined above the haulage (3060) level, with the exception of drift pillars and smaller blocks such as in No. 44 stope.

No. 16. The lower level on the North Drift vein exposes the vein below the ore body and most of the upper drift is caved, so little is known of this ore body. Surface subsidence extends over a distance of 300 feet, and the body probably was mined for this length.

No. 17. The ore body of the Ehrman vein is exhausted and most of the workings caved. L. A. Palmer [114] stated that the ore body was as much as 15 feet wide. The north end of the shoot coincides with branching shear zones carrying a small ore body (see pl. 43). The southern limit is coincident with a cross fault having a 5-foot displacement. The south plunge of the body is determined by these bounding structures.

No. 18. The Roadcut vein is exposed in the road and in a short drift 60 feet below the surface exposures. It may be on the southern extension of the southeast branching shear zone of the Diamond vein (see pl. 42).

No. 19. Surface outcrops are the main exposures of No. 5 vein (see pl. 42). Only traces of magnesite are found in the prospect drifts at the 3,240 and 3,500 levels. The vein strikes toward the north end of the Diamond vein, of which it may be a branch.

No. 20. Surface outcrops, some of which have been trenched, are the only exposures of the veins in the North Prospects area. Near the summit of Red Mountain, three veins, as much as 200 feet long, trend N. 20° W., N. 60° W., and N. 70° W. Exposures are inadequate to determine the attitude of the veins or the continuity and grade of the ore.

No. 21. The ore body of the White Queen vein (see pl. 46) has been mined out above the 3,340 level. At this level the ore seems to be pinching downward.

No. 22. The main (north) ore body of No. 6 vein is the largest in the Red Mountain district (see pl. 46). With the exception of the stockwork and nodular material in the wide hanging-wall breccia, the south end has been mined out above the 3,080 level and the north end has been mined out above the 3,135 level.

The footwall is strong and contains up to 6 feet of silica and magnesium silicate minerals. A few large nodules of pure magnesite are in this zone, probably carried there during silica mineralization. A calcite vein up to 3 feet wide also is emplaced in the footwall. The pronounced

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[114] Op. cit., p. 746.

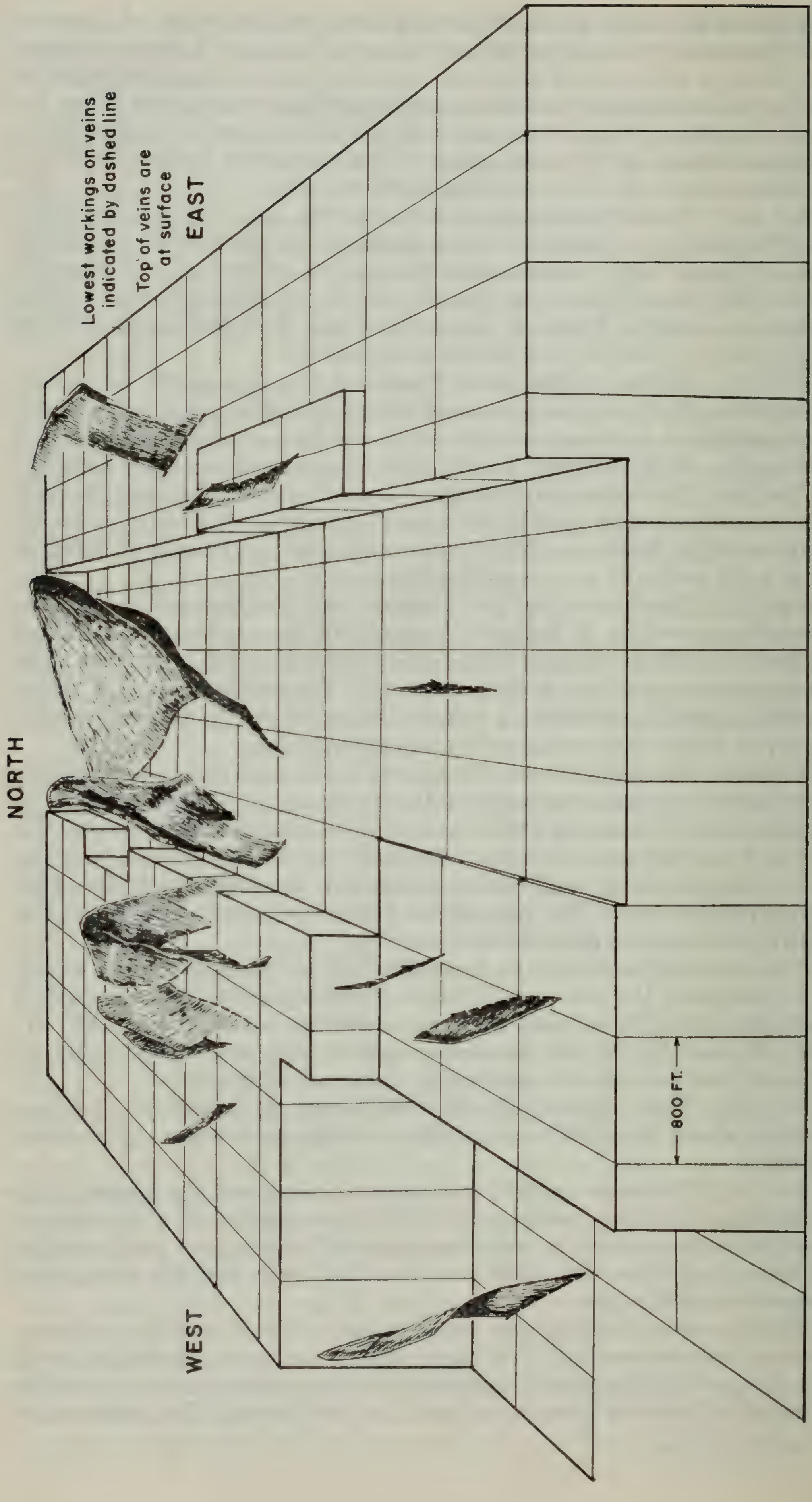
NORTH
Lowest workings on veins indicated by dashed line
Top of veins are at surface
EAST
WEST
800 FT.

FIGURE 7. Block diagram of White Diamond-Silver vein group.

effect of localization of ore by structures has been described. North of the main shoot some magnesite is found, but here the vein is characterized by heavy silica and magnesium silicate deposits. South of the main body are two small shoots pinching at elevations of 3,055 and 3,170 feet. The southernmost shoot, bottoming at 3,055 feet, carries heavy silica and magnesium silicate deposits and is located where strong shears branch from the main shear zone. The southern bodies are mined out.

No. 23. Only surface croppings indicate the presence of No. 27 vein, which may be as much as 150 feet long and up to 4 feet wide. A short exploratory tunnel did not reach the ore body.

No. 24. No. 9 vein (see pl. 46) is mined out above the 3,280 level. The body was thinning upward, so the main part of the body may still be unmined.

No. 25. No. 9 south ore body is mined out above the 3,135 level and the workings are caved, so little is known about the vein.

No. 26. No. 15 ore body (see pl. 46) is in a branching shear zone of No. 6 vein. The body is mined out above the 3,300 level. An exploratory drift at 3,230 feet follows the vein but does not reach the main lens.

No. 27. The ore body of No. 6 split is mined out. The 3,170 level exposes the vein below the main part of the body.

No. 28. The ore body of No. 8 vein has been mined out above the 3,390 level (see pls. 46, 47). Minable magnesite is limited to the south of a bend in the vein. A long crosscut was driven to intersect the vein on the 3,230 level, but did not reach ore.

No. 29. No. 16 vein ore body is exposed on the surface, and in exploratory drifts on the 3,340 and 3,530 levels (see pls. 46, 47). None of these indicate that the body is large, but there is a 100-foot length of minable ore on the 3,530 level. The body was being developed by raising from the 3,340 level to find the bottom of minable ore.

No. 30. The ore body of No. 23 vein (see pl. 46) is in a branching shear zone at the south end of No. 6 vein, and the body has been mined out above the 3,035 level. Most of the ore is nodular; some is massive. Widths up to 9 feet over a length of 200 feet are seen on the 3,035 level and indicate that prospects of continuation of ore at depth are good.

Magnesite croppings as much as 4 feet wide are exposed on a spur of the ridge 200 feet west of the south end of No. 23 ore body.

No. 31. Three ore bodies occur on the Pacific vein (see pl. 48); all of them are mined out. The north body was mined from 3,010 feet to the surface; the central body was mined from the 3,100 level to the 3,190 level; and the south body was mined from the 3,190 level to the surface. Much silica is found in the vein, and this material has contaminated considerable magnesite, lowering the grade sufficiently to make it unminable. The ore bodies developed where strong shears branched from the very irregular main shear zone.

Red Mountain Mine

The Red Mountain mine, also known as the Patterson mine, is on the northeast flank of Red Mountain (pl. 38). The magnesite veins cut across spurs and gullies of the Hideout Creek tributaries. The lower workings, 2,200 feet in elevation, are about 2,400 feet west and 500 feet above the Kronkheit Ranch on Hideout Creek. The surface workings of the main vein, at a maximum elevation of 2,570 feet, are about 1,100 feet below the ridge crest and 2,300 feet east-northeast of the White Queen vein in the Western mine deposits. The area is in the NW$\frac{1}{4}$ sec. 17, T. 6 S., R. 5 E., and is covered by four claims owned by T. L. James. The deposits can be reached via the Patterson-Del Puerto Road. Twenty-three miles from Patterson, the road turns south and follows Del Puerto Creek. At this point, a poor road continues west and northwest for 1 mile to the Kronkheit Ranch, where a trail leads up a tributary valley to the lower level of the mine. The upper level of the mine can be reached by following a poor road branching northwestward from the Patterson-Del Puerto Road three quarters of a mile south of the Hideout Creek fork. The upper road is 2 miles long, ending at the mine. The upper and lower levels are connected only by trail.

The deposits consist of two mineralized shear zones (pl. 49), the larger called the Main vein and the smaller known as the Secondary, or Columbia, vein. The deposits and the mine are described in considerable detail in the Bureau of Mines report,[115] which gives a comprehensive picture of the history, extent of operations, and description of the ore bodies. However, the writer does not agree with the Bureau engineer on the genesis of the deposits, and considers the ore estimates to be much too high.

The magnesite deposits have the same mineralogic and structural features as have been described for the deposits in the Western mine area. Most of the magnesite is nodular and is accompanied by fissure-filling deposits in brecciated areas. Some magnesite has been mylonitized along the northern part of the main shear zone. The ore is accompanied by silica and magnesium silicate minerals, but no calcite occurs with the mineral assemblage.

The Main vein carries three principal ore bodies, called the north, middle, and south bodies, as well as one small shoot between the north and middle bodies. The vein strikes N. 18° W. along the very regular northern part of the vein and curves eastward to strike N. 30° W. at the south end of the vein (pl. 49). The dip averages 70° SW. with minor local variations. The ore bodies were mined from surface workings and from two levels, one at 2,200 feet and the other at 2,400 feet elevation; in addition, the south body was mined from a drift at 2,485 feet elevation. All commercial ore has been mined from the 2,400 level to the surface; only the north body has been mined between the 2,200 and the 2,400 levels.

The largest deposit, the north ore body, is about 240 feet long. It is in a wide serpentinized shear zone at least 60 feet wide at the surface and 55 feet wide on the 2,200 level. Two large lenses consisting of nodular to massive magnesite form the main part of the deposit at the surface. The lenses are as much as 140 feet long, total 34 feet in width, and are separated by serpentine. At depth, the ore body pinches to a vein 2 to 3 feet wide, which widens here and there to 13 feet (pl. 49). The wider shoots are nodular at depth. On the 2,200 level, the southern end of the ore body contains some pink mylonitized magnesite and is contaminated by silica deposited in shattered magnesite.

The middle ore body is exposed only on the lower level, where the ore is nodular and of medium grade, and averages 2 feet in width for a length of 80 feet. The south ore body is exposed in surface cuts and on the lower level. Surface cuts indicate the ore body may have been 170 feet long and possibly 5 feet wide. On the lower level, the magnesite is nodular and usually 1 foot wide over a distance of 60 feet. A small ore body, lying between the north and middle bodies and exposed on the 2,400 foot level only (pl. 49), is 70 feet long and consists of scattered nodules in a 6 foot wide serpentine zone; it has been mined to the leached and weathered surface zone.

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[115] Op. cit.

All ore bodies are located where shear planes branch from the main shear-plane wall. The small middle and southern bodies occur where minor shears branch, but the north body occurs south of the junction of the main shear zone with a strong mineralized split on the east side of the zone. The branching shear carries a short body consisting of nodular ore up to 10 feet wide.

The Secondary, or Columbia vein [116] nearly parallels the Main vein and is about 300 feet to the west. Some exposures of magnesite have been trenched, but the showings are very small. The southernmost exposure has been trenched and a crosscut driven to the vein 80 feet below the surface. In both workings less than 1 foot of magnesite is exposed.

The reserves of the Main vein ore bodies are small. The south end of the north body has an unmined block between the 2,200 and 2,400 levels, but as it was not taken when the main part was being mined, the operators must have considered the material to be too lean for profitable mining. Therefore, the only ore left in this block lies below the 2,200 level. There is a heavy flow of water at this level, and operators would have to consider the expense of pumping in development. A small tonnage is left in the middle body, both above and below the 2,200 level. At best, this ore is of medium grade. The south ore body is not wide enough for mining.

Security Deposit

The Security deposit is on a southwesterly spur of Red Mountain (see pl. 38); a valley separates the spur from the No. 12 vein area of the Western mine. The deposit is 1,600 feet north of the lower No. 12 vein, on a very steep slope about 200 feet above the floor of the valley. The valley is occupied by a small intermittent stream flowing southwestward and joining Sweetwater Creek 3,800 feet southwest of the deposits. Access to the mine is by a poor road which leaves the Livermore Road at the Jotem Down Tavern, follows Sweetwater Creek 1,000 feet north to the junction with the tributary, and parallels the tributary the remainder of the distance. The road is passable by car to a ranch house 1,700 feet northwest of the junction; beyond, the road is abandoned and washed out. The deposits are in the NE¼ sec. 13, T. 6 S., R. 4 E., and on the Security mining claim now leased by the Westvaco Chlorine Products Corporation (see pl. 39). The mine has been closed since the first World War, when the Standard Magnesite Company leased the property and mined several thousand tons of ore, mainly from surface cuts. Transportation of ore from the mine to the road was via a wooden surface chute. Some of the ore may have been calcined in a stack kiln 1,500 feet downstream from the mine. No mining equipment is left at the property, and the chute and kiln are in ruins. The stream could furnish adequate water for 6 months of a year, but wells would have to be drilled to insure a year-round supply.

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[116] U. S. Bureau of Mines, op. cit., pp. 8-10.

The country rock is dunitic, containing less enstatite than the country rock in the vicinity of the Western mine. Deposits are in a serpentinized shear zone as much as 30 feet wide, which trends north up the slope. The main ore body consists of a branching vein which can be traced for about 200 feet in the shear zone, striking N. 5° E. and dipping 78° SE. A strong split on the east side of the vein strikes N. 25° W. and dips vertically. Both the vein and split contain magnesite, mainly low- to medium-grade nodular ore. The main vein carries as much as a 4-foot width of nodular magnesite, the split contains much less. Minor amounts of silica and magnesium silicate minerals accompany the ore. In addition, several other small magnesite veins and veinlets are in the area.

The principal workings are drifts on the main vein and along the split at an elevation of 2,890 feet, and surface cuts on the ore body above the drifts. In addition, there is some surface trenching on the smaller veins and an exploratory drift below the main level. Exposures indicate the deposit is not large and reserves therefore are small.

Fidelity Deposit

The Fidelity deposit is on a small spur projecting southward from Red Mountain and is 1,000 feet west-northwest of the Security deposit (see pl. 38). The valley separating the two deposits is drained by a northeast branch of the tributary flowing south of the Security deposit. The deposit can be reached by following the road from Sweetwater Creek to the ranch house southwest of the Security deposit. Only a trail follows the northeast branch of the stream from the ranch house to the Fidelity deposit, a distance of 1,900 feet. The deposit is about 100 feet above the stream bed. The mineralized area is in the SE¼ sec. 12, T. 6 S., R. 4 E., on the Fidelity mining claim now leased by the Westvaco Chlorine Products Corporation (see pl. 39). The deposit has never been operated, the only development work consisting of several shallow trenches cut in the larger veins. Water supply is limited, and wells probably would have to be drilled to supplement the amount obtained from the intermittent stream below the deposit.

The country rock is dunite; the deposits consist of veins and stockworks in a crush zone roughly 100 feet long and 100 feet wide. The three larger veins are as much as 7 feet wide, containing deposits of nodular and stockwork magnesite. The veins strike generally north, dip steeply east or west, and are connected by smaller irregular veins and stockworks. Most exposures consist of low-grade magnesite. Reserves are small.

Chromite Deposits

Stringers of granular chromite occur in the dunite body north and northeast of the Security deposit, and in small dunitic lenses about 400 feet west of the crest of Red Mountain, between the No. 8 and the No. 16 magnesite veins (pls. 38, 39). All are small, and the material is of low grade. No deposits comparable to the size of those mapped by Hawkes and others [117] occur in the part of the intrusive body mapped in connection with the magnesite studies.

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[117] Op. cit.

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MINES AND MINERAL RESOURCES OF ALAMEDA COUNTY, CALIFORNIA

BY FENELON F. DAVIS *

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* Assistant mining engineer, California State Division of Mines. Manuscript submitted for publication September 1949.

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ABSTRACT

Alameda is one of the central Coast Range counties, lying on the eastern shore of San Francisco Bay. It contains a land area of 733 square miles and supported a population of 745,000 in 1949. A northwest-trending alluvial plain 3 to 8 miles in width constitutes the west border of the county. This plain rises from the tidal waters of the bay to an elevation of about 100 feet at its eastern inner margin. Here the Hayward fault, a persistent zone of structural weakness, separates the plain from the uplifted Berkeley Hills on the east. This is the dominant range in the uplifted block between the bay and Mount Diablo in Contra Costa County. Along the southwest flank of the range, the Franciscan formation of Jurassic age, composed of sandstones, shales, cherts, schists, and associated basic intrusives of peridotite altered to serpentine, is exposed. These rocks are overlain unconformably by Cretaceous sandstones and shales which extend over the summit of the ranges east of Hayward. The general dip of the Cretaceous sediments is northeastward, and they are flanked on the east by strips of upper and middle Miocene marine sediments forming the west limb of a syncline. The Miocene is in places covered by Pliocene sediments of continental origin interbedded with volcanic flows.

The principal drainage system of the county is located in the southeastern part where the surface exposures are rocks of the Franciscan formation. The Franciscan-covered area slopes northwestward and is overlain by Quaternary-Pliocene gravels in the low hills which form the south border of the Livermore Valley.

The Livermore Valley is bordered on the north by the southern tip of the Mount Diablo foothills where volcanic rocks of Pliocene age are exposed. It is closed on the east by the Altamont Hills along whose western base a probable fault has been mapped.

Large resources of salines, sand, gravel, pottery clay, brick clay, and miscellaneous stone exist in Alameda County. Sodium chloride (the salt of daily usage) is the principal saline product, and is obtained by solar evaporation of sea water along the eastern shore of San Francisco Bay in the vicinity of Newark. Bitterns from the salt plants are the source of magnesium compounds. The production of magnesium compounds from sea water has largely replaced the use of magnesite as a source material for these products. Additional by-products of salt production are bromine and potash. Clay obtained from Quaternary deposits of the Niles alluvial cone provides the raw material for ceramic and brick-making plants in the county. Small amounts of high-grade clays have been produced intermittently from the steeply dipping Eocene beds near Tesla. The excavation of sand and gravel from Quaternary deposits at Niles and from Quaternary-Pliocene deposits in the Livermore Valley constitutes an important phase of the mineral industry of Alameda County. In addition, numerous quarries for the production of crushed rock are distributed throughout the Berkeley Hills from central Oakland to Niles. Most of these quarries are located in the cherts, metamorphosed sandstone, and associated rocks of the Franciscan formation. A small amount of chromite was produced at Cedar Mountain during the first world war. Coal classed as sub-bituminous was produced from the steep-dipping Eocene beds near Tesla. Over a 6-year period beginning in 1897 production averaged 70,000 tons annually. There has been practically no production of coal since 1902. Deposits of manganese associated with the cherts of the Franciscan formation southwest of Livermore produced small quantities of ore prior to and during World War I. A small quantity of manganese ore was also produced during World War II. A moderate amount of pyrite was produced annually from 1891 to 1934. The pyrite occurred at Leona Heights in a narrow belt of rhyolite which extends through the hills from Berkeley to Decoto. An extensive deposit of oyster shells in the southern part of San Francisco Bay has supplied neighboring industrial plants with a low-cost raw material of high lime content for many years. The following commercial minerals are known to occur in Alameda County and production in small quantities has been reported: magnesite, molding sand, mineral paint, asbestos, travertine, soapstone, copper, and silver.

INTRODUCTION

History

The Spanish explorers visited the territory which is now Alameda County in 1769, but no permanent settlement was established until 1797.[1] In the latter year the Franciscan Fathers began construction on the Mission San Jose de Guadalupe, which prospered and increased in size until it became the second largest in the chain of 21 missions extending from San Diego to Sonoma. A population of 1,877 was reached by 1831. During this period a number of extensive land grants were made to Spanish settlers, first by the King of Spain and later by the Mexican government. They included Rancho San Antonio (Oakland vicinity) in 1820, Rancho Los Rositas (Livermore) 1835, Rancho San Leandro 1837, and Rancho San Lorenzo (Hayward vicinity) in 1841.

The period of American occupation began in 1847, and Oakland was incorporated in 1852. In 1853 Alameda County was formed from parts of Santa Clara and Contra Costa Counties. The new county received its name from El Arroya de la Alameda (Alameda Creek), ''a place where poplar trees grow.'' The College of California began its existence in Oakland in 1854, and became the University of California in 1869. This seat of learning was moved to Berkeley in 1873. The population of the county increased to nearly 94,000 in 1890. A short time later utility developments and realty subdivisions were begun which laid the foundation for the later residential and industrial growth of the area.

Geography

Alameda County is an elbow-shaped territory situated on the eastern shore of San Francisco Bay. One arm extends northwestward along the bay for a distance of about 35 miles, while the other arm extends eastward for a similar distance. A total area of 840 square miles is included within the county boundaries, which may be divided into 733 square miles of land area and 107 square miles of water area. It is bounded on the north by Contra Costa County, on the east by San Joaquin County, and on the south by Santa Clara County.

Alameda County presents an unusual combination of city, suburban, and country life, which is intimately associated with, yet distinct from, business, industrial, and shipping activities. Included in the county are the cities of Albany, Berkeley, Emeryville, Oakland, Piedmont, Alameda, San Leandro, and Hayward, which form a continuous community fronting along the bay. Beyond a low range of hills to the eastward are the incorporated towns of Livermore and Pleasanton. The population of the entire county was estimated at 745,000 by the Oakland Chamber of Commerce in July 1949.

The western portion of the county enjoys an equable climate. Here, the mean temperature ranges from 43° Fahrenheit in January to 72° Fahrenheit in July. In the Livermore Valley the mean summer temperature reaches a maximum of 88°. The average annual rainfall ranges from 23 inches at Oakland to 14 inches in the Livermore Valley.

The terminals of three transcontinental railroads, the Southern Pacific, the Santa Fe, and the Western Pacific, are located in Oakland, where they connect directly with docking facilities. About 100 steamship lines make Oakland a port of call. The major highways radiate in all directions from the metropolitan center. The 2,930-acre Oakland municipal airport is a western terminal for transcontinental airlines. When the present expansion program is completed, this port will have a class 9 rating.

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[1] Alameda County, California Blue Book, pp. 457-468, 1946.

Topography and Geology

Alameda is one of the central Coast Range counties lying on the eastern shore of San Francisco Bay. The general surface geology of the county is shown on the Geologic Map of California,[2] scale 1 to 500,000, or approximately 1 inch to 8 miles. Detailed geological maps and reports on parts of the county have been made by Branner,[3] Lawson,[4] and Huey.[5]

Topographic maps on a scale of 1 to 62,500 or about 1 inch to 1 mile are available for the entire county. The mapping was done by the U. S. Geological Survey and includes the following quadrangles: Byron, Carbona, Concord, Hayward, Mt. Diablo, Mt. Hamilton, Palo Alto, Pleasanton, San Francisco, San Jose, San Mateo, and Tesla.

Alluvium of Quaternary age is exposed along a northwestward-trending plain 3 to 8 miles in width which constitutes the west border of the county. This plain rises from the tidal waters of the bay to an elevation of about 100 feet at its eastern inner margin. Here the Hayward fault, a persistent zone of structural weakness, separates the plain from the uplifted Berkeley Hills on the east. This is the dominant range in the uplifted block between the bay and Mt. Diablo in Contra Costa County. Elevations of about 2000 feet are attained in the Berkeley Hills. Along the southwest flank the Franciscan formation of Jurassic age, composed of sandstones, shales, cherts, schists, and associated ultrabasic intrusives of peridotite (altered to serpentine), is exposed. These rocks are overlain unconformably by Cretaceous sandstones and shales which extend over the summit of the range east of Hayward. The Cretaceous dips northeastward, and it is flanked on the east by strips of upper and middle Miocene marine sediments forming the west limb of a syncline. The Miocene is in places covered by Pliocene sediments of continental origin interbedded with volcanic flows.

In the southeastern part of the county a maximum elevation of about 3,800 feet is attained. Here are located the headwaters of Arroyo Mocho, Arroyo de Valle, and Alameda Creek, which form the principal drainage system of the county. The surface exposures in this drainage system consist of rocks of the Franciscan formation, which cover about 110 square miles. The streams flow northwestward to the Livermore Valley, which covers about 70 square miles in the north-central part of the county, then westward through Niles Canyon, across the alluvial plain, and into the bay at Alvarado. This Franciscan-covered area slopes northwestward and is overlain by Quaternary-Pliocene gravels in the low hills which form the south border of Livermore Valley.

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[2] Jenkins, Olaf P., Geologic map of California, scale 1:500,000, California Div. Mines, 1938.

[3] Branner, J. C., Report on the underground water conditions of the Livermore Valley and of Sunol Valley—the future water supply of San Francisco, pp. 209-222, Spring Valley Water Company, 1912.

[4] Lawson, Andrew C., Report on the underground water supply of Livermore Valley—the future water supply of San Francisco, pp. 222-230, Spring Valley Water Company, 1912. . . . Lawson, Andrew C., U. S. Geol. Survey Geol. Atlas, San Francisco folio (no. 193), 24 pp., 1914.

[5] Huey, A. S., Geology of the Tesla quadrangle: California Div. Mines Bull. 140, 75 pp., 1948.

Livermore Valley is bordered on the north by the southern tip of the Mt. Diablo foothills, where volcanic rocks of Pliocene age are exposed. It is closed on the east by the Altamont Hills along whose western base a probable fault has been mapped.

The surface near Altamont is covered by marine sandstones and shales of Upper Cretaceous age which are anticlinal in structure. South of T. 2 S., the Cretaceous is overlain by upper Miocene marine sediments over a wide area, through which the Cretaceous occasionally appears in fault contact. The Miocene near Tesla is flanked on the south by a thin strip of upper Eocene marine sediment. On the west Livermore Valley is bounded by the Berkeley Hills, along whose eastern base the Calaveras fault has been mapped.

Industries[6]

Manufacturing is the principal industry of Alameda County. In 1947 an estimated total of 1350 manufacturers did an annual volume of business estimated at $650,000,000. The plants of more than 200 nationally known manufacturers are included in these figures.

Ample electric energy for industry, at relatively low cost, is provided by the Pacific Gas and Electric Company through its system of hydroelectric plants, transmission and distribution lines, supplemented by steam electric-generating plants at key cities. Table 1 shows the cost of industrial lighting and power when recorded on the same meter.

Table 1. Cost of industrial lighting and power.

Demand	Monthly delivery	Average cost per KW hour
1000 KW	400,000 KWH	$0.0085
	200,000 KWH	$0.0110
300 KW	120,000 KWH	$0.0094
	60,000 KWH	$0.0124
75 KW	30,000 KWH	$0.0117
	15,000 KWH	$0.0156

Natural gas is piped into Alameda County from the Rio Vista gas field and the Kettleman Hills oil field. Construction has started on a new 34-inch high-pressure natural-gas transmission line which will bring natural gas into central California from Texas and New Mexico. A 30-inch feeder from the Pacific Gas and Electric Company distributing station at Milpitas will serve Alameda County. Fuel oil and gasoline are available from the neighboring refineries of four major oil companies. Table 2 shows the cost of industrial gas in this area.

Table 2. Cost of industrial gas.

Monthly delivery	Average cost per therm (100,000 B.T.U.)
500,000 therms	2.60 cents
50,000 therms	2.76 cents
5,000 therms	3.46 cents

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[6] How to win the markets of the west (a brochure), Oakland Chamber of Commerce, 1948.

A twin aqueduct 93 miles long brings soft mountain water to the cities of Alameda County and to a large unincorporated area. This water is supplied to consumers at a cost ranging from 22 to 12 cents per hundred cubic feet. The former figure applies to the first 3300 cubic feet of water, and the latter figure applies to quantities in excess of 333,300 cubic feet per month.

Alameda County has a varied agricultural industry with a 1948 total production of more than $37,128,000. Over 243,000 acres are devoted to agriculture. The following crops are produced: apricots, cherries, peas, tomatoes, spinach, rhubarb, cauliflower, grapes, flowers, and seeds. Poultry, dairy products, and livestock are also important items in the total production.

MINES AND MINERAL RESOURCES

Alameda County ranked eleventh among the 58 counties of the state in value of mineral production for 1947. The following minerals, having a total value of $8,497,176, were produced in that year: bromine, clay, limestone (bay shells), magnesium compounds, salt (sodium chloride), sand and gravel, and stone. The quantity and value of this production is shown in table 3.

Table 3. Mineral production from Alameda County during 1947.

Product	Quantity	Value
Clay products, heavy clay (other than pottery and refractories)	----------	[1] $1,165,000
Clay, raw	18,751 short tons	18,782
Salt (sodium chloride)	540,943 short tons	3,046,907
Sand and gravel	3,844,057 short tons	3,578,314
Stone	1,112,500 short tons	714,025
Unapportioned (bromine, lime, crude magnesite, and magnesium compounds)	----------	1,139,148
Total value	----------	$8,497,176

[1] According to U. S. Bureau of the Census; value not included in county total.

Other minerals which have been produced in commercial quantities from this county are: chromite, coal, manganese, and pyrite. The following commercial minerals are known to occur in Alameda County and production in small quantities has been reported: asbestos, asphalt, copper, lead, limestone, magnesite, mineral paint, potash, sand (molding), silver, soapstone, and travertine. Occurrences of the minerals mentioned below have been reported in Alameda County by various investigators, and some descriptions of the approximate localities have been listed by Murdoch and Webb:[7] albite, alunogen, actinolite, analcite, anauxite, aragonite, bornite, boothite, bronzite, calcite, chalcanthite, chalcocite, chalcopyrite, chlorite (kämmererite), cinnabar, copiapite, epsomite, gold, gypsum, hydromagnesite, lawsonite, melanterite, natrolite, petroleum, pisanite, pyrophyllite, quartz, sphalerite, stibnite, and zircon. Geodal agate (chalcedony) has been found in the Berkeley Hills rhyolite, north of the Fish Ranch road. Specimens of crocidolite, lepidolite, and gypsum were seen at the Scott ranch house in Arroyo Mocho. Mineral constituents of the volcanic rocks (andesite, basalt, and tuff) of the Berkeley Hills, have been described by Lawson[8] after microscopic study. Essential minerals are augite, plagioclase feldspar (andesine, labradorite, bytownite anorthite); accessory minerals are apatite, hypersthene, magnetite, olivine, orthoclase feldspar, and glass; secondary minerals are analcite, calcite, chalcedony, chlorite, iddingsite, limonite, natrolite, opal, quartz, and serpentine. The minerals analcite, calcite, chalcedony, natrolite, opal, and quartz, also occur over extensive areas as amygdules filling the vesicular portions of the volcanic rocks. Most of the amygdules are almond-shaped and range from microscopic size to 6 inches along their major axis. Some amygdules consist of outer shells of chalcedony, lined with quartz crystals or calcite, surrounding a central cavity. In other amygdules the order of deposition is reversed with calcite forming the outer shell.

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[7] Murdoch, Joseph, and Webb, Robert W., Minerals of California: California Div. Mines Bull. 136, 402 pp., 1948.

Table 4 shows the amount and value of mineral production in Alameda County from 1890 to 1947. The important mineral products are described in alphabetical order below. The numbers following the mine or plant names refer to the numbered locations on the accompanying map of Alameda County. A tabulated list at the end of the report includes inactive and unproductive mines and prospects.

Asbestos

Massive serpentine, the host rock for most asbestos deposits, is widely distributed throughout California. The Geologic Map of California[9] shows that outcrops of serpentine are distributed throughout the Berkeley Hills and in the hills south of the Livermore Valley.

A small tonnage of short-fiber asbestos was mined from a small deposit in the N½ sec. 36, T. 1 S., R. 3 W., in 1915 and 1918. The fiber was mixed with magnesite and used by the John D. Hoff Asbestos Company in the manufacture of asbestos stucco, flooring, and steam-pipe covering.

Bromine

Bromine is produced from waste sea-water bitterns obtained from salt works. The first production was reported in 1926.

Westvaco Chemical Corporation[10] (California Chemical Corporation) *(14)* is located approximately in the NW¼ sec. 11, T. 5 S., R. 2 W., M. D., about 1½ miles southwest of Newark. Officers are William B. Thom, president, 405 Lexington Avenue, New York City; and H. L. Bradley, plant superintendent, Newark, California.

The company was incorporated in Delaware on December 15, 1926, as Westvaco Chlorine Products Corporation.[11] On January 30, 1937, the company acquired the assets of the California Chemical Company and its subsidiaries, National Kellastone Company and Chemical Reduction Company, through an exchange of stock. The Sierra Magnesite Company is a subsidiary and a producer of raw materials. A new magnesia plant was completed and placed on production at Newark in November 1937. On August 31, 1944, the company purchased 95 percent of the stock of Barium Products Limited of California from United Chemicals Incorporated. The company adopted the above-mentioned name on April 28, 1948. In September 1948 the company became part of the Food Machinery and Chemical Corporation and is now designated as Westvaco Chemical Division. It is an important producer of industrial chemicals and mineral products which are sold to large groups of basic industries. The plants at Newark are located on fee land and land held under long-term lease.

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[8] Lawson, Andrew C., and Palache, Charles, The Berkeley hills—a detail of Coast Range geology: Univ. California Dept. Geol. Bull., vol. 2, no. 12, pp. 349-450, 1901.

[9] Jenkins, Olaf P., op. cit., 1938.

[10] Laizure, C. McK, Alameda County: California Div. Mines Rept. 25, pp. 442-443, 1929.

[11] Industrial securities, Moody's Manual of Investment, p. 1517, 1948.

Although early attempts had been made to recover additional minerals from the residual bitterns of solar salt production, they had been generally unsuccessful and resulted only in returning the bitterns to the sea. The California Chemical Corporation in 1923 developed to the point of commercial operation certain extractive processes designed to utilize these sea-water bitterns as the raw material. As a result, long-term contracts were negotiated with the principal salt producer for the purchase of the bitterns—formerly a waste material. About 400 gallons of bitterns are obtained from each ton of salt produced. The analysis of a typical sea-water bittern of 30° Baumé gravity follows:

*Table 5. Composition of sea-water bitterns.**

Mineral constituent	Symbol	Percent	Tons per million gallons
Sodium chloride (salt)	$NaCl$	12.5	656
Magnesium chloride	$MgCl_2$	8.7	457
Magnesium sulphate	$MgSO_4$	6.1	320
Potassium chloride	KCl	1.9	100
Magnesium bromide	$MgBr$	0.18	9.2

* Seaton, Max Y., Bromine and magnesium compounds drawn from the western bays and hills: Chem. Met. Eng., vol. 38, no. 11, 1931.

The bitterns are drained from the salt crystallizing ponds and pumped to bittern ponds which cover more than 80 acres near Newark, and have a capacity of about 200,000,000 gallons. A certain amount of salt (sodium chloride) crystallizes from the bitterns during the storage period. After the bitterns have been removed the storage ponds are flooded with sea water to redissolve and remove the salt which is returned to the bay. The empty storage ponds are then ready to receive the new supply of bitterns provided annually during the summer and fall months of the salt-production season.

Bromine is recovered from the bitterns by an interesting process. Submerged centrifuged pumps transfer the raw alkaline bittern from the ponds to a surge tank. The bittern is neutralized with concentrated sulphuric acid to facilitate processing, sent to the plant storage reservoirs,

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Table 4. Mineral production of Alameda County, 1890-1947

Year	Brick		Chromite		Pottery clay		Coal		Manganese		Pyrites		Salt		Miscellaneous stone,[2] value	Miscellaneous and unapportioned		
	M	Value	Tons	Value	Tons	Value	Tons	Value	Tons	Value	Tons	Value	Tons	Value		Amount	Value	Substance
1890	----	----	[1] 397	$534	----	----	[1]	----	[1]	----	----	----	[1]	----	----	----	----	
1891	----	----	257	344	----	----	----	----	----	----	----	----	----	----	----	----	----	
1892	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	
1893	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	
1894	7,500	$37,500	----	----	----	----	----	----	468	$4,962	----	----	44,450	$125,125	$73,463	1,265 cu. ft.	$1,000	Building stone.
1895	12,000	60,000	----	----	----	----	----	----	600	5,400	----	----	43,810	114,575	94,372	500 cu. ft.	300	Sandstone.
1896	7,000	35,000	----	----	----	----	----	----	318	3,415	----	----	55,826	122,810	69,405	----	----	
1897	6,500	35,750	----	----	----	----	21,900	$50,370	504	4,080	----	----	61,353	139,830	73,300	----	----	
1898	7,000	35,000	----	----	----	----	70,500	176,250	440	2,102	----	----	87,800	155,812	73,845	2,000 cu. ft.	750	Sandstone.
1899	10,000	60,000	----	----	----	----	80,703	242,109	290	3,090	----	----	78,434	137,088	66,512	----	----	
1900	5,000	40,000	----	----	----	----	91,731	332,066	130	1,300	----	----	64,718	158,674	107,551	30 tons	180	Magnesite.
1901	9,590	67,130	----	----	----	----	87,424	262,272	423	4,365	4,500	$18 000	114,450	324,136	107,201	13,728 lbs. 190 tons	2,162 1,100	Copper. Magnesite.
1902	10,000	60,000	----	----	----	----	67,850	203,550	870	7,140	14,323	53,301	80,000	160,000	182,295	1,500 lbs. 100 tons	52 500	Lead. Magnesite.
1903	10,300	82,400	----	----	----	----	[3]	----	----	----	21,811	88,500	76,877	143,605	200,702	10,000 tons	15,000	Lime.
1904	10,500	90,000	----	----	----	----	[3]	----	60	900	15,043	62,992	52,990	76,340	284,181	----	----	
1905	12,000	95,500	----	----	----	----	----	----	----	----	15,503	63,958	49,100	54,200	449,029	----	----	
1906	21,345	413,750	----	----	10,000	$10,000	----	----	----	----	14,000	56,000	68,450	126,838	496,482	500 tons	1,750	Glass sand.
1907	28,770	474,350	----	----	12,610	14,299	----	----	----	----	16,482	54,410	54,922	163,127	512,607	1,416 tons	14,400	Asphalt.
1908	1,800	10,800	70	595	16,370	44,822	----	----	260	4,680	13,404	70,782	78,462	108,694	465,653	11,943 tons 3 tons 250 tons	143,376 48 625	Asphalt. Soapstone. Glass sand.
1909	14,800	140,000	[3]	----	45,348	205,194	----	----	----	----	8,015	40,516	104,978	214,808	340,208	18,290 tons ----	241,475 233,032	Asphalt. Unapportioned, 1900-09, inclusive.
1910	20,919	195,889	69	552	9,541	63,925	----	----	----	----	10,938	53,170	131,868	285,217	408,591	18,290 tons 40 tons	197,783 260	Asphalt. Soapstone.
1911	19,660	153,330	60	500	10,500	8,300	----	----	----	----	6,340	31,352	121,540	201,542	404,615	----	----	
1912	12,800	133,100	----	----	----	----	----	----	20	360	7,267	29,068	126,211	212,150	420,283	----	----	
1913	13,977	122,937	----	----	3,000	2,700	----	----	----	----	6,029	24,128	129,318	233,388	456,064	5,000 bbls.	5,000	Lime.
1914	22,668	159,205	----	----	5,000	1,000	----	----	----	----	9,829	34,696	126,983	292,641	381,135	50 tons 150 tons 10 tons	250 1,500 20	Limestone. Magnesite. Limestone.
1915	14,841	132,765	----	----	----	----	----	----	319	3,652	11,287	45,148	103,768	220,977	457,381	----	1,740	Asbestos, chromite, pottery clay.
1916	23,551	315,941	612	7,344	4,060	2,750	----	----	562	9,005	16,394	65,110	111,206	263,773	403,587	----	26,657	Limestone, magnesium chloride, magnesite.
1917	and tile	290,033	52	960	6,502	4,524	----	----	1,211	30,250	[3]	----	148,846	315,970	413,845	----	83,141	Lime, limestone, magnesite, magnesium salts, potash, pyrites.
1918	----	258,812	220	14,600	2,675	3,850	----	----	2,746	109,874	9,113	45,565	130,132	410,345	311,320	----	19,169	Asbestos, magnesium salts, potash, limestone.
1919	----	369,778	80	1,264	5,011	12,127	----	----	[3]	----	8,978	42,902	157,751	552,178	309,572	----	16,864	Magnesium salts, manganese, potash.
1920	----	664,918	----	----	3,001	3,762	----	----	[3]	----	10,602	55,251	145,368	574,837	620,758	----	28,354	Magnesium salts, manganese, mineral paint, potash.
1921	----	365,853	----	----	6,079	7,405	----	----		----	13,449	70,669	108,925	370,296	513,641	----	25,826	Magnesium salts, manganese, mineral paint, potash.
1922	----	[3]	----	----	[3]	----	----	----	130	1,020	[3]	----	139,556	434,076	760,422	----	845,936	Brick, hollow building tile, magnesium salts, pyrite.
1923	----	828,048	----	----	2,850	10,422	----	----	----	----	[3]	----	177,389	585,585	965,465	----	97,515	Magnesium salts, pyrite.
1924	----	763,476	----	----	2,482	1,124	----	----	----	----	[3]	----	189,217	635,653	1,158,886	----	75,506	Magnesium salts, potash, pyrite.
1925	----	938,375	----	----	9,300	11,376	----	----	----	----	[3]	----	180,712	497,692	1,414,398	----	54,665	Magnesium salts, potash, pyrite.
1926	----	808,779	----	----	5,870	7,183	----	----	----	----	[3]	----	202,777	628,470	1,642,618	----	71,414	Bromine, magnesium salts, pyrite.
1927	----	587,402	----	----	6,593	20,516	----	----	----	----	[3]	----	180,623	366,346	1,538,017	----	65,506	Magnesium salts, potash, pyrite.
1928	----	505,386	----	----	27,189	17,071	----	----	----	----	[3]	----	224,000	611,888	1,267,155	----	20,330	Pyrite, travertine.
1929	----	304,326	----	----	7,037	6,980	----	----	----	----	[3]	----	264,666	1,623,397	1,592,232	321,844 lbs. 104 fine oz. ----	48,016 55 51,717	Copper. Silver. Mineral paint, pyrite.
1930	----	307,712	----	----	10,103	20,063	----	----	----	----	[3]	----	232,808	694,371	1,436,608	41 fine oz. ----	16 70,567	Silver. Copper, pyrite.
1931	----	248,569	----	----	5,505	3,048	----	----	----	----	[3]	----	[3]	----	1,008,124	----	1,158,184	Bromine, limestone (shells), pyrite, salt.
1932	----	161,001	----	----	7,333	4,887	----	----	----	----	[3]	----	[3]	----	813,165	12,545 lbs. 49 fine oz. ----	790 14 785,282	Copper. Silver. Limestone (shells), pyrite.
1933	----	179,152	----	----	4,101	3,496	----	----	----	----	[3]	----	[3]	----	649,105	----	1,097,908	Lime, limestone (shells), mineral paint, pyrite, salt.
1934	----	192,527	----	----	[3]	----	----	----	----	----	[3]	----	[3]	----	1,090,371	----	1,096,735	Clay (pottery), bromine, lime, limestone, pyrite, salt.
1935	----	218,988	----	----	3,782	3,282	----	----	----	----	----	----	[3]	----	681,555	27,104 lbs. ----	2,250 1,104,418	Copper. Bromine, lime, limestone, salt.
1936	----	146,730	----	----	6,612	6,443	----	----	----	----	----	----	[3]	----	1,222,909	----	1,037,033	Bromine, lime, salt.
1937	----	[3]	----	----	5,506	9,712	----	----	----	----	----	----	[3]	----	1,361,781	----	1,104,809	Brick and tile, bromine, lime, salt.
1938	----	[3]	----	----	5,244	5,532	----	----	----	----	----	----	[3]	----	1,141,554	----	1,348,514	Brick and tile, bromine, lime, magnesium salts, salt.
1939	----	[3]	----	----	10,434	17,073	----	----	----	----	----	----	[3]	----	1,325,914	----	1,345,600	Brick and tile, bromine, lime, salt.
1940	----	[3]	----	----	6,860	10,349	----	----	----	----	----	----	[3]	----	1,559,545	----	2,127,754	Brick and tile, bromine, lime, magnesite,[4] salt.
1941	----	[3]	----	----	12,372	19,607	----	----	----	----	----	----	[3]	----	2,372,864	----	2,054,674	Brick and tile, bromine, lime, magnesite,[4] salt.
1942	----	[3]	----	----	8,435	9,668	----	----	[3]	----	----	----	[3]	----	3,914,518	----	2,188,608	Brick and tile, bromine, copper, gypsum,[4] lime, magnesite,[4] manganese ore, salt.
1943	----	[3]	----	----	[3]	----	----	----	[3]	----	----	----	[3]	----	3,359,657	----	1,977,260	Brick and tile, bromine, clay (pottery), gypsum,[4] magnesite,[4] magnesium salts, salt.
1944	----	[3]	----	----		----	----	----	[5]	----	----	----	[3]	----	6,112,065	----	1,976,961	Brick and tile, bromine, clay (pottery), copper, gypsum,[4] lime (shells), magnesium salts, manganese ore, salt.
1945	----	[3]	----	----	8,269	7,519	----	----	[3]	----	----	----	[3]	----	4,643,264	----	2,011,156	Brick and tile, bromine, gypsum,[4] lime (shells), magnesia, manganese ore, salt.
1946	----	[3]	----	----	9,566	16,166	----	----	----	----	----	----	[3]	----	3,120,783	----	1,723,365	Brick and tile, bromine, gypsum,[4] magnesia, salt.
1947	----	[5]	----	----	18,751	18,782	----	----	----	----	----	----	540,943	3,046,907	4,292,339	----	1,139,148	Bromine, lime (shells), magnesium compounds.
Totals	----	[3] $11,090,212	[3] 1,817	$26,693	[3] 323,891	$614,957	[3] 420,108	$1,266,617	[3] 9,351	$195,595	[3] 233,307	$1,005,518	[3] 4,991,227	$15,383,361	$59,142,912	----	$27,744,020	

Grand total value, $116,469,885

[1] There was some production of chromite, manganese, and salt in Alameda County in the years previous to those here shown but the separate county figures are not available.

[2] Includes crushed rock, macadam, ballast, rubble, rip-rap, sand, gravel.

[3] See under Unapportioned.

[4] Precipitated from sea water.

[5] Not segregated by counties.

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and pumped to an overhead supply tank. The liquid then flows through a feed-regulating, constant-level float box and heat exchangers to the top of the three bromine-separation towers. Steam is introduced at the bottom of the tower and chlorine gas at an intermediate point. These three elements properly proportioned result in the separation of a bromine vapor which escapes to a stone condenser near the upper part of the tower. A gravity separation of the condensed water and liquid bromine is effected. The chlorine is removed by distillation and returned to the tower for reuse. Each of the towers can handle 2,000 gallons of bitterns per hour and make a bromine recovery of over 95 percent. This plant can also manufacture ethylene dibromide. Ethyl alcohol is dehydrated to prepare a pure ethylene gas and the latter is brought in contact with the bromine at low pressure to form the desired end-product.

The bromine-free liquid escaping from the bottom of the bromine towers is treated for the recovery of magnesium chloride. This may be done in vacuum evaporators similar to those used for the production of refined salt. The salt, sodium chloride, separates from the hot liquid and subsequent cooling causes separation of the remaining minerals as a pure saturated solution. The magnesium chloride is then isolated from the magnesium sulphate, potassium chloride, and residual sodium salts by settling and centrifuging. The magnesium chloride solution is refined by further evaporation in open ponds, and then is chilled to produce the solid magnesium chloride of commerce.

Chromite

Chromite, $FeCr_2O_4$, has been mined intermittently in small quantities near Cedar Mountain in the southeastern part of the county. The chromite occurs both as segregated masses and as disseminated grains in a body of serpentine which has been intruded into the surrounding sandstones and shales of the Franciscan formation. Although earlier reports [12] state that production from this area ranged from 3,000 to 6,500 tons, the recorded production of chromite shown in table 4 totals only 1,817 tons. Most of the chromite was produced from the Newman (Mendenhall) mine (11) in the west-central part of sec. 26, T. 4 S., R. 3 E. There has been no reported production since 1919.

Clay

Since common clay is a widely distributed, low-priced mineral product, it cannot be produced competitively by high-cost methods involving long-distance transportation charges. The presence of favorable marketing and manufacturing conditions has induced a number of ceramic manufacturing companies to establish plants in Alameda County. The best deposits of common clay suitable for the manufacture of brick, sewer pipe, and roofing tile, are located in the Livermore Valley and on the Niles alluvial cone. These clays are mined by surface methods. The plants have been extremely active since the end of World War II in 1945, owing to the large increase in population in the bay area.

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[12] Aubury, L. E., Chromite in Alameda County: California Min. Bur. Bull. 38, p. 276, 1906.

Harder, E. C., Some chromite deposits in western and central California: U. S. Geol. Survey Bull. 430, p. 173, 1909.

Bradley, W. W., Huguenin, E., Logan, C. A., Tucker, W. B., and Waring, C. A., Manganese and chromium in California: California Min. Bur. Bull. 76, p. 115, 1918.

Huguenin, E., and Castello, W. O., Alameda County: California Min. Bur. Rept. 17, p. 20, 1920.

Huey, Arthur S., op. cit., p. 59, 1948.

Numerous steep-dipping clay beds were encountered in the coal-mining operations near Tesla, beginning in 1897. These clays ranged from red-burning to high-grade plastic fireclay, and were mined by underground methods. The high cost of producing clay from below the surface caused cessation of operations about 1912. Dietrich[13] summarizes the future possibilities of the Tesla district as follows:

> "The district must still be considered as an important potential source of high-grade fireclays, as there seems little doubt that extensive prospecting would demonstrate the presence of many millions of tons of fireclay that would be equal, if not better, in quality to any refractory clays now being mined in California. There is little justification at present, however, for attempting to rejuvenate clay mining in the district, as the fireclay deposits at Ione, Amador County, and at Lincoln, Placer County, are adequate in quality and quantity for present needs, and are cheaply mined, mainly from surface workings, whereas underground mining under difficult conditions would be necessary if extensive operation were to be carried on at Tesla."

California Faience Company (The Tile Shop)[14] is located at 1335 Hearst Avenue, Berkeley. The owner is W. L. Bragdon.

High-quality custom-made art tile, glazed art pottery, decorative inserts, fountains, and ornamental garden ware are manufactured in this plant. Shipments are made to all parts of the country. Although production was curtailed during World War II, a considerable business has since been developed to supply the firing requirements of ceramic hobbyists.

A red-burning clay from Angel Ranch, Humboldt County, is blended with Ione clay. The clays are ground in a ball mill and pugged by hand. The art pottery is shaped by casting. The molds are made of plaster of paris, and 75 to 100 casts can be made from each mold. The tile and inserts are hand pressed in plaster molds. Colors are made by special formulae, the pigment being ground in one of three small pebble mills. The colors are applied by hand or with a small fine-nozzle pressure gun. The shaped products are shop air-dried, and drying is completed in a gas-fired baking oven. Firing is done in one of two Denver kilns, one electric fired and the other gas fired, the higher temperature being attained in the latter. The firing period ranges from 10 to 12 hours and a temperature of more than 1900° Fahrenheit is reached. Biscuit and glaze firing are done simultaneously, the biscuit ware being placed in the hottest part of the furnace (cone 04). Cooling requires about 36 hours. The owner and a helper are employed in the plant.

California Pottery Company[15] *(1)* is located approximately in the NE$\frac{1}{4}$ sec. 15, T. 4 S., R. 1 W., M.D., projected, about 1$\frac{1}{2}$ miles northeast of Niles.

Officers are Burton B. Brace, president, and George A. Mays, superintendent and general manager.

A brown, red-burning clay is mined from a pit on the property and is blended with a buff-colored clay trucked in from a company-owned deposit at Valley Springs. The blend consists of about 75 percent local clay and is used to make sewer pipe in sizes ranging from 4 inches to 24 inches in diameter.

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[13] Dietrich, Waldemar Fenn, The clay resources and the ceramic industry of California: California Div. Mines Bull. 99, pp. 38-49, 1928.

[14] Dietrich, Waldemar Fenn, op. cit., p. 39, 1928.

[15] Dietrich, W. F., The clay resources and the ceramic industry of California: California Div. Mines Bull. 99, p. 39, 1928.

Local clay from the pit, which is about 30 feet deep and 100 feet wide, is removed to the outdoor drying shed by Diesel scraper. The sewer-pipe mix is prepared by batch-weighing and dry-pan grinding. It passes to a storage bunker and is withdrawn as required. The mix is pugged in a wet-pan mill and passed to the steam-operated pipe press. After removal from the press, the pipe is placed on the drying floor for about a week, and is then ready for kiln-loading. There are nine round down-draft periodic-type kilns about 30 feet in diameter. The kilns are gas fired and are equipped for oil-burning change-over on short notice. Each pair of kilns is served by a rectangular stack about 70 feet high. The pipe is burned on a 8-day cycle which includes setting the kiln, burning, cooling, and drawing. Firing is done at 2200° Fahrenheit (cone 7). The soft-mud shaping process is used in making pipe joints and special fittings. This sticky mud is ''worked'' on a potters wheel, hand pressed into plaster molds, removed, and placed on the drying floor.

After removal from the kiln the finished sewer pipe is stock piled or shipped to construction jobs via motor truck. The plant is operating on one shift, 5 days per week, and produces 1500 tons of sewer pipe (burned weight) per month. A small quantity of chimney pipe and drain tile is also produced. Seventy-five men are employed at the plant.

Christye Ceramic Shoppe is a small ceramic shop at 366 24th Street, Oakland, operated for the benefit of hobbyists. Commercial firing of small ornamental custom-made ware is also undertaken. The body is provided by a Marysville clay. The objects are cast or hand pressed and fired for 10 to 20 hours in an electric kiln. Colors are made according to formula and are ground in a small pebble mill. Instruction is provided to those interested in ceramic art.

N. Clark and Sons Division, Pacific Clay Products [16] *(2)* main office is located at 306 West Avenue 26, Los Angeles; the plant is at 401 Pacific Avenue, Alameda. Officers are president, Ray Lacy; plant superintendent, Bradley Wyatt.

The N. Clark and Sons organization was founded in Sacramento in 1864, and the Alameda plant was established in 1887. It became a division of Pacific Clay Products on July 1, 1945, and is one of four units operated by that company in the state.

Pacific Clay Products was incorporated in California on March 26, 1923, as Pacific Clay Products, Inc. It acquired the business of Pacific Clay Products Company, incorporated in 1910 as Pacific Sewer Pipe Company. The present name was adopted in 1925.

The capital stock consists of an authorized 156,250 shares of $10 par stock, of which 109,864 shares were outstanding in 1948. Dividends of 15 cents per share have been paid annually since 1942. The stock is listed on the San Francisco and Los Angeles stock exchanges. The price range in 1947 was $12½ to $17.

Structural terra cotta (ceramic veneer) and sewer pipe are the principal products of this plant. Sewer pipe is made in sizes ranging from 4 to 24 inches in diameter. The smaller sizes, up to 8 inches in diameter, are made in 3-foot lengths; the larger sizes are made in 4-foot lengths. Chimney pipe, flue lining, and quarry tile are also manufactured. Clay purchased in the Livermore Valley is shipped in by rail and blended with Ione (Amador County) clay obtained from a deposit owned by the company. The shipped-in clay is transferred to storage sheds and withdrawn as needed for either of three dry-pan grinding machines. The ground clay is discharged to bucket elevators and removed to storage bins. In making pipe the ground clay passes to a F.H.R. twin-screw auger, where water is added, and then by a 15-foot enclosed conveyor belt to the pipe press. Units of the desired length are severed by an automatic wire cutter and the pipe is stored for 4 days in a drying room maintained at a temperature of 100° Fahrenheit. The firing cycle requires about 12 days. The 24-inch diameter pipe is fired for 8 days, reaching a maximum temperature of 2150° Fahrenheit. Four additional days are required for cooling before the kiln is unloaded.

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[16] Dietrich, W. F., op. cit., p. 40, 1928.
Boalich, E. S., and others, op. cit., p. 36, 1920.
Aubury, L. E., The structural and industrial materials of California: California Min. Bur. Bull. 38, pp. 202, 207, 1906.

Structural terra cotta is made in three types (1) hand made, which is hand pressed in plaster moulds. Hand-made terra cotta is used primarily in public buildings and for ornamental purposes. (2) Anchor, which is extruded from dies, using a sewer pipe press. The larger sizes, exceeding 20 by 36 inches, are usually of this type. (3) Adhesion, which is extruded from dies, using a combined auger and de-airing machine. The smaller sizes, less than 20 by 36 inches, are usually of the adhesion type.

The raw clay for terra cotta is worked by the wet-pan grinding process. After extrusion, the units are dried, spray-glazed, and fired. With the exception of the anchor type, all terra cotta units are fired in a muffle kiln. The firing cycle requires 9 days: 4½ days firing, and 4½ to 5 days cooling. A temperature of 2050° Fahrenheit is attained. The units are then removed to the fitting room and cut to specifications. Since each piece is ''custom-made'' for its particular place in a specified building, no stocks of terra cotta are kept on hand.

There are 13 down-draft and 6 muffle kilns in this plant. The kilns are 26 feet in diameter, about 15 feet high, and are served by two cylindrical stacks 125 feet and 150 feet in height. The plant has a capacity of 750 tons of fired product per month, employs 125 men, and is operated on a one-shift, 8-hour day, 5 days per week. The firing crew is employed on a 24-hour day.

Gladding, McBean and Company (W. S. Dickey Clay Manufacturing Co., Livermore Fire Brick Works[17]*)* plant is located approximately in the NW¼ sec. 17, T. 3 S., R. 2 E., M.D., at the west end of Livermore. Officers are: Atholl McBean, chairman; F. B. Ortman, president, 2901 Los Feliz Boulevard, Los Angeles; and Charles Perry, plant manager, Livermore.

The business of this company was established in 1875, and the original company was incorporated in 1886. The present company was incorporated in California on April 28, 1924. It acquired the American Fire Brick Company in 1929; the Pacific Coast properties of American Encaustic Tiling Company, Ltd., on August 1, 1933; the Stockton Fire Brick Company, and the Clay Corporation of California on December 11, 1943; the controlling interest in Denver Terra Cotta Company, and the assets of Emsco Refractories Company of California in October 1944.

The capital stock of the company consists of an authorized 500,000 shares of par $25 stock, of which 210,000 shares were outstanding in

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[17] Dietrich, Waldemar Fenn, op. cit., p. 40, 1928.
Boalich, E. S., Castello, W. O., Huguenin, Emile, Logan, C. A., and Tucker, W. Burling, The clay industry in California: California Min. Bur. Prelim. Rept. 7, p. 37, 1920.

1948. Dividends of $1 per share were paid in 1947 and $1.50 per share in 1948. The stock is listed on the San Francisco and Los Angeles exchanges. The price range in 1948 was $24 to $36¼.

This plant is engaged in the manufacture of refractory firebrick. Operations began in 1943. Buff-colored fire-clay from company owned deposits at Lincoln, Placer County, is shipped in and unloaded from a siding directly into the storage sheds. The raw clay is fed to the dry-pan grinding machines by means of a mobile hopper and short conveyor belt. After grinding, the clay passes by bucket elevator to the screens and then to a Bonnet single-screw auger where water is added. The mix is extruded as three narrow ribbons of stiff mud. An automatic wire-cutting machine simultaneously cuts each ribbon into four brick units which are carried by belt conveyor to one of two stamping machines. Here, the company name and brick type are imprinted on each unit. The units are hand-loaded to narrow-gauge cars, hand-trammed a short distance, and the cars are transferred to standard-gauge carriages. The latter are hand-trammed to the drying tunnels which are equipped with two sets of narrow-gauge tracks to accommodate the cars. There are 10 drying tunnels in parallel, each about 70 feet in length. After drying, the bricks are loaded into the kilns for firing. There are six round 10-burner gas-fired down-draft kilns, about 26 feet in diameter, serviced by two rectangular stacks about 50 feet high. Two smaller muffle kilns, about 15 feet in diameter, are serviced by one 50-foot stack. Special joints and fittings are hand-molded. This plant is now idle, having been closed February 28, 1949.

Gladding, McBean and Company (4) is located approximately in the SE¼ sec. 20, T. 2 S., R. 3 E., M.D., on the south side of the highway a quarter of a mile southwest of Altamont station.

A small quantity of shale from the Panoche formation of Upper Cretaceous age has been used by this company for blending purposes at its plants in Lincoln, Placer County, and Livermore, Alameda County.

The quarry consists of two small benches. The lower bench is about 30 feet wide and 150 feet long with a 20-foot vertical face. The upper bench is about 30 feet wide and 100 feet long with a 20-foot vertical face. At this point the beds strike N. 55° W. and dip 12° SW. The formation consists of layers of brown sandy shale alternating with layers of gray clay shale. The latter is fissile, assumes a tan color on exposure to the agents of weathering, and breaks away from the face to form a talus of small flakes. Many of the clay shale layers are about a quarter of an inch thick; the sandy shale layers range from thin layers to 3 inches in thickness.

Interlocking Roof Tile Company (5) is located in sec. 17, T. 4 S., R. 1 W., M.D., projected, about 1 mile west of Niles on Highway 101 Alternate. It is owned by J. Pessagno and Sons.

This plant, situated on a 12-acre tract, was built in 1927 to make an interlocking roof tile of special design. The plant was closed during World War II and resumed operation in 1947. Brown and yellow clay, mined from a trench-pit on the property, is run through a hammer-mill which reduces the particles to minus 4 mesh. The clay passes by chute to an auger mixing machine (pugmill) where water is added and the desired consistency is attained. The mixture proceeds through an air-removing chamber and is extruded onto a conveyor belt as a ribbon of stiff mud. An automatic wire cutting machine divides the ribbon of mud into units, each of which contains three horizontal slabs. The slabs are removed from the conveyor and placed in an automatic revolving press for shaping. The press produces 10 to 12 units per minute, which are placed on pallets and stacked in an indoor drying room where they remain for 5 days. Firing is done in one of three gas-fired down-draft kilns. The large kiln is about 12 feet high, 30 feet in diameter, and has a capacity of 12,000 units. The two smaller kilns have a capacity of 9000 units each. The firing cycle requires about 14 days. The maximum temperature attained during firing is about 1900° Fahrenheit and this temperature is maintained for 2 days. All temperatures are controlled by pyrometer. The fired tile is permitted to remain in the kiln for about a week to permit slow cooling, and is then removed to the stock pile. The plant employs 8 men working one shift on a 5½-day week.

Kraftile Company[18] *(6)* is located approximately in secs. 17 and 18, T. 4 S., R. 1 W., M. D., about 1¾ miles west of Niles on the Alvarado road. Officers are C. W. Kraft, president, and L. R. Alt, plant superintendent of Niles, California.

This company produces the following structural clay products: glazed structural wall and partition units, glazed swimming-pool overflow gutters, patio tile, quarry tile, standard and Roman face brick, acid floor brick, and acid tank block. The wall units are hollow with a nominal face size 6 x 12 inches, and thickness of 2, 4, or 6 inches. Practically all the products are made in modular coordinated sizes. They are finished in a permanent, non-absorbent, clear buff-colored glaze; or in a ceramic glaze offering a wide range of non-fading colors. They provide a finished wall or wainscot requiring no furring, plastering, painting, or maintenance. Fire clay is used in the body of these units and they are carefully made by machine extrusion under vacuum. Face and thickness tolerances are held to 2 percent of the standard dimensions and distortion of face or edges cannot exceed 0.5 percent. The exposed faces are glazed and burned at high temperatures to make the glaze and body inseparable. The glaze must be free from imperfections such as crawling, crazing, or other defects that result in an objectionable appearance when viewed at a distance of 5 feet. The closed sides and back are scored for mortar or plaster except when a smooth finish is specified. A heavy corrugated-paper padding protects the units from chipping in shipment. The overflow gutters are terra cotta, made by extrusion from a die under vacuum. The exposed surfaces are covered with a ceramic glaze, with a non-slip glaze on the top surface, and burned at high temperature. The patio tile is formed under vacuum and burned to a warm red color. It presents a dense, hard, abrasion-resisting surface and is made in the following sizes: 12 by 12 inches, 6 by 12 inches, and 6 by 6 inches. Thickness is seven-eighths of an inch, permitting easy handling and low cost installation. They may be installed on a mortar bed over a concrete or wooden floor. Face bricks are machine-extruded under vacuum to produce a dense compact body with minimum absorption and staining. Two shapes are made: standard, 2⅝ by 7⅝ (face) by 3⅝ inches; and Roman, 1½ by 11½ (face) by 3½ inches. Acid-proof red floor brick are hard burned and will withstand all acids and alkalis common to food plants. They will not discolor and are available in either smooth or anti-slip surfaces for industrial or commercial floors.

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[18] Dietrich, W. F., The clay resources and the ceramic industry of California: California Div. Mines Bull. 99, p. 40, 1928.

Local red clay used in these products is obtained from a 35- by 100- by 15-foot trench on the premises and is removed by a bulldozer to bins in the storage shed. Buff clay shipped in from Cooperstown and Lincoln is transferred from railroad cars to the storage shed by Town-motor lift truck equipped with a scoop. The clay charge to the dry-pan grinding mill is prepared on a batch scale where barium carbonate and waste tile are added. This charge is ground to 20 mesh and the oversize is returned for regrinding. Water is added to the feed as it enters a twin screw Hummer auger where it is mixed, blended, and extruded as a block-ribbon to an American wire cutting machine. The latter is hand operated, to permit making units of various lengths. The cut units pass to a 15-foot horizontal conveyor belt from which they are hand-loaded to cars running on 24-inch rails. The cars are hand-trammed a short distance and transferred to ''carriages'' running on standard gauge track set normal to the narrow track. The ''carriages'' transport the cars to the entrance of the drying tunnels where they are again transferred to narrow-gauge tracks running through the hot air dehydrator drying tunnels. There are eight gas-fired tunnels about 75 feet long equipped with two sets of 24-inch rails. Drying requires 48 to 120 hours depending upon the size and thickness of the unit.

After drying the redware is fired in one of the five round down-draft 25 foot diameter kilns. Each kiln is equipped with 10 burners. Draft for the group of kilns is provided by two square stacks about 50 feet high. Redware remains in the kilns 12 to 15 days after loading. The pre-heating and cooling periods are included in this time interval. A maximum temperature of about 1900° Fahrenheit is attained. Temperature control is maintained by a combination of pyrometric cone and pyrometer.

Buff ware to be glazed is transported from the drying tunnel to an adjoining building where the units are carefully machine-trimmed to size. The units are then transferred to a horizontal belt conveyor passing through alternately spaced spray booths and drying boxes. One coat of slip and two coats of color glaze are sprayed on the units. Each coat is 0.016 of an inch thick. The glazed blocks are replaced on the narrow-gauge tunnel kiln cars and run through a pre-heater about 10 feet long. The cars pass from the pre-heater to a 185-foot gas-fired Harcop continuous tunnel kiln. The pre-firing zone is about 70 feet long. The firing zone is about 40 feet long and is equipped with 12 burners, six on each side. The cooling zone is about 70 feet long. The firing cycle required 3 days, one day in each section of the kiln. After firing the units are inspected, packed in cartons or trays and shipped, or placed in the storage warehouse. All glazes are carefully prepared, according to formulae, in a separate department. Ground feldspar, silica, talc, hydrate of aluminum, zirconium oxide, and coloring compound are some of the additional raw materials used in this plant.

The plant operates on a 5½-day week, using two shifts in the ''making'' department and three shifts in the burning department. About 85 people are employed (including office staff), and the plant has a fired-product capacity of 1,000 tons per month.

Laclede-Christy Clay Products Company is located approximately in the E½ sec. 35, T. 5 S., R. 1 W., M.D., projected, about 1½ miles southeast of Warm Springs on State Highway 17, a quarter of a mile southwest of the highway. Officers are J. A. Kayser, manager, 391 Sutter Street, San Francisco, and W. J. Eames, superintendent, Warm Springs.

A plant consisting of an office, warehouse, and one down-draft kiln, has been constructed, and began operations on December 1, 1948. This plant makes refractory tank blocks used for lining glass-making furnaces. These blocks are designed for use in all locations in contact with molten glass, and are sold under the trade name ''Fluxtite''.

Carefully selected Missouri bond clays are weathered, blended, and treated, to obtain a mix having the desired purity, plasticity, and strength. The mix is alternately pugged and aged to secure uniformity, and the blocks are manufactured by a de-airing process. They are carefully dried and their moisture content is constantly checked before burning. Specially developed machines are employed for kiln loading. The blocks are burned in a gas-fired down-draft kiln, about 15 by 26 feet in size. A very high peak-temperature is maintained over a considerable period of time to insure soaking heat and uniformity of burn. The changes in temperature are carefully controlled at all points in the burning cycle. The complete burning cycle requires about 30 days and production capacity runs about 2,000 pounds of fired-product. After burning, the blocks are machine-ground to size, 12 by 24 by 36 inches, for speed and accuracy in laying with resultant low cost of installation.

Leisurely Yours. Sophie Madson, 3101 Shattuck Avenue, Berkeley, operates a small ceramic shop for hobbyists. A ball clay, obtained from the Los Angeles area, provides the body. Firing is done in an electric kiln between the limits of cones 05 and 07 (about 1900° Fahrenheit). The firing period is 5½ hours. Instruction in ceramic art is also provided.

M. and S. Tile Company [19] *(8)* plant is located in sec. 7, T. 4 S., R. 1 W., M.D., projected, at Decoto, near the Oakland-Niles highway, U. S. 101 Alternate. The pit is located in the S½ sec. 1, T. 4 S., R. 2 W., M.D., projected, on Whipple road east of the railroad tracks. Owners are F. J. Thomas, G. L. Smith, and J. M. Bettencourt.

The plant was built in 1926 to manufacture antique (thigh-shaped) hand-made and machine-made roofing tile. It was closed during World War II but resumed operations in 1946. Clay is mined with a Diesel scraper and trucked about a mile to the plant storage bin. The clay is prepared by dry-grinding and pug-milling. It is then either machine pressed or hand molded on a paper-covered form. The units are placed on drying racks for 24 hours and loaded to either of two gas-fired rectangular down-draft kilns. Kiln capacity is about 5,700 units. The firing schedule consumes about 60 hours, finishing temperature is 1900° Fahrenheit. Eight men are employed by this company.

Merritt Supply Company is located at 6121 San Pablo Avenue, Oakland, California. Manager is Dewey Coleman.

This company has provided an outlet for the products of a ceramic plant located at 1289 Cedar Street, Berkeley. Since 1940 the plant has made porcelain stove blocks, story-book dolls, and specialities, from a white-burning clay obtained in southern California. The dolls were made by casting in plaster of paris moulds. Firing was done in two circular up-draft kilns. A clay press is also included in the plant equipment. The plant was closed in June 1949 on completion of their last order, and the company is now seeking contracts for a line of new products to be made at the plant. The Electrical Porcelain Works [20] operated this plant during 1936 and 1937.

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[19] Dietrich, Waldemar Fenn, op. cit., p. 41, 1928.

Westinghouse Electric and Manufacturing Company [21] is located at 6121 Green Street, Emeryville, California.

The manufacture of high-voltage porcelain insulators was discontinued at this plant in the spring of 1943. All porcelain products are now made at the Derry, Pennsylvania, plant of the company. Feldspar from Campo, California, and some California clays were used in these products.

Coal[22]

Coal was discovered at Tesla in Corral Hollow prior to 1857 [23] but no substantial production was reported until 40 years later. From 1897 to 1902 inclusive, production from this district averaged more than 70,000 tons per year. Most of the production was from the Tesla mine (12) in sec. 25, T. 3 S., R. 3 E. The geology was described by George Otis Smith [24] as follows:

> "The Corral Hollow fields are in rocks of Eocene (Tejon) age . . . but here the faulting is more extensive and the dips of the coal beds . . . being from 30° to 80° (northeasterly).
>
> "There are a number of seams but the productive ones are the Eureka and the Summit. The Eureka has been developed to a considerable extent and is 10 to 12 feet in thickness. The roof is solid sandstone but the floor is less satisfactory. The Summit seam averages 7 feet of clean coal and has an excellent floor of hard sandstone, but the roof is slate, which from its shaly character involves expense in timbering."

A generalized geologic section through the main Tesla shaft [25] shows that the coal seams occupy the south limb of a syncline trending northwestward. Additional geologic sections near the mine have been prepared by Huey.[26] The Eureka seam was sampled by E. W. Parker of the U. S. Geological Survey at two widely separated points in 1905. These samples were analyzed (see table 6) and classed as sub-bituminous B by the U. S. Bureau of Mines.[27]

Additional analyses are contained in an earlier report.[28]

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[20] Dietrich, Waldemar Fenn, op. cit., p. 40, 1928.

[21] Dietrich, Waldemar Fenn, op. cit., pp. 45-49, 1928.

[22] Goodyear, W. A., Coal: California Min. Bur. Rept. 7, pp. 146-148, 1887.
Irelan, Wm. Jr., Alameda County: California Min. Bur. Rept. 8, pp. 26-30, 1888.
Goodyear, W. A., Alameda County: California Min. Bur. Rept. 10, pp. 91-95, 1890.
Crawford, J. J., Coal, Alameda County: California Min. Bur. Rept., 12, p. 39, 1894.
Huguenin, E. and Castello, W. O., Alameda County: California Min. Bur. Rept. 17, p. 21, 1920.
Laizure, C. McK, Alameda County: California Min. Bur. Rept. 25, p. 433, 1929.

[23] Goodyear, W. A., Notes descriptive of conditions of the Corral Hollow coal mines: Geol. Survey of California, vol. 2. p. 35, 1870.

[24] Smith, George Otis, U. S. Geol. Survey, 22d Ann. Rept., pt. 3, pp. 501-504, 1902.

[25] Dietrich, Waldemar Fenn, op. cit., p. 44, 1928.

[26] Huey, A. S., op. cit., 1948.

[27] Analyses of Arizona, California, Idaho, Nevada, and Oregon coals: U. S. Bur. Mines, Tech. Paper 696, pp. 34, 51, 1947.

[28] Lord, N. W., and others, Analyses of coals in the United States: U. S. Bur. Mines Bull. 22, p. 53, 1913.

Table 6. Analyses of coal samples from Tesla mine.

Proximate (percent) ultimate

	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Calorific value B. T. U.
Sample 1606	17.6	41.1	23.3	18.0	2.9	----------
Dried at 106° C.	----------	49.9	28.2	21.9	3.5	----------
Sample 1607	18.0	39.2	26.4	16.4	3.1	8,110
Dried at 106° C.	----------	47.8	32.2	20.0	3.7	9,890

Mineral-matter free basis.

	Fixed carbon dry basis (percent)	Calorific value, dry basis	B. T. U. moist basis
Sample 1606	37.3	----------	----------
Sample 1607	41.4	12,710	9,870

The method of working the mine was described as follows:[29]

> "The Tesla mine in Corral Hollow is opened by both a tunnel and a shaft, and the breast and pillar system is used . . . The coal from the Eureka seam is screened and washed, but that from the Summit seam is sufficiently clean to go direct to the bunkers."

There has been no coal production reported from this district since 1904.

Copper and Silver

Native copper crystals in arborescent groups have been obtained from a body of pyrite, containing some chalcopyrite, at the Alma mine, sec. 34, T. 1 S., R. 3 W. As a result of secondary oxidation of the sulphides, a number of sulphates of iron and copper were formed in the vicinity of the mine. The secondary copper minerals are boothite, $CuSO_4 \cdot 7H_2O$; chalcanthite, $CuSO_4 \cdot 5H_2O$; and pisanite, $(Fe, Cu)\ SO_4 \cdot 7H_2O$. Both the primary and secondary minerals have been described by Schaller.[30] The ore from the neighboring Leona mine was said to average 1½ percent copper.

The pyrite was mined and shipped to Stege, Contra Costa County, where the Stauffer Chemical Company used it to make sulfuric acid.[31] In this process the ore was roasted and the sulfur was removed as SO_2 gas. The roasted ore was accumulated and was later treated at the adjoining plant of the Blowski Copper Company. Here the copper was leached out of the pyrite residue and was reprecipitated as cement copper. Some copper was also obtained by heap leaching the Alma mine dump. More than 375,000 pounds of copper valued at more than $53,000 was obtained by these methods, chiefly during the period 1929-35. No pyrite was mined after 1934. A small production of copper was made in 1942 and 1944, by treating accumulated pyrite residues. A fire destroyed the leaching plant in 1947.

Silver in the amount of 194 fine ounces, valued at $85.00, was also recovered as a by-product.

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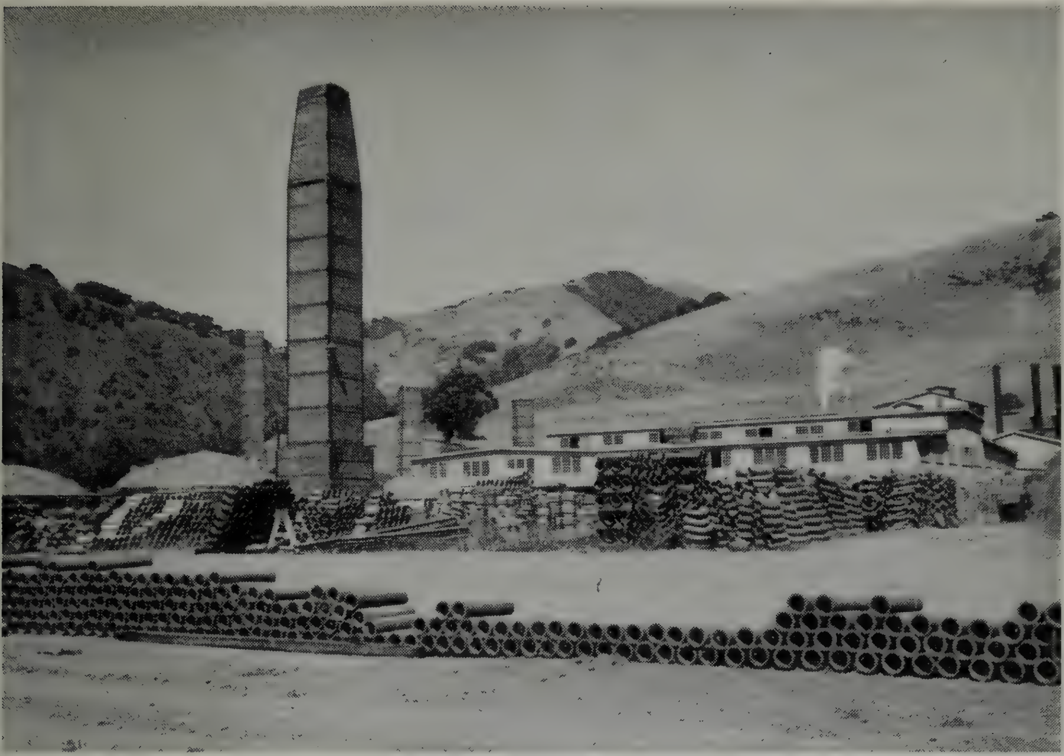
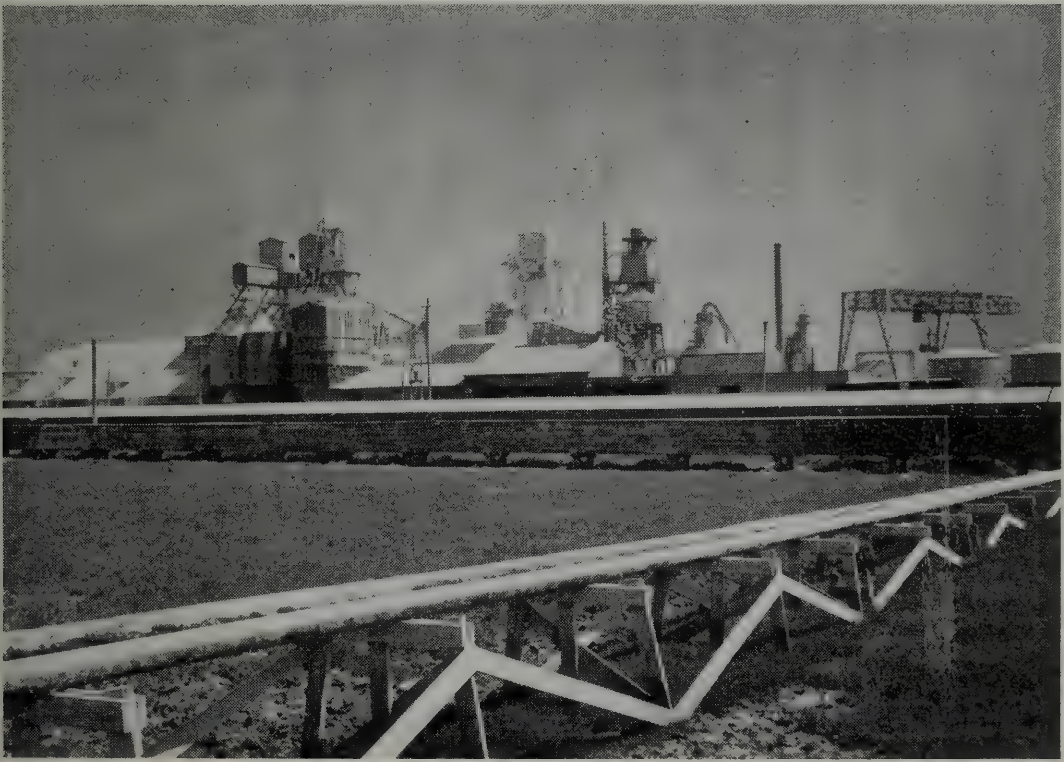
[29] U. S. Geological Survey, Annual report, pt. 3, pp. 501-504, 1902.

[30] Schaller, Waldemar T., Minerals from Leona Heights, Alameda County, California: Univ. California, Dept. Geol Sci. Bull., vol. 3, pp. 191-217, 1903.

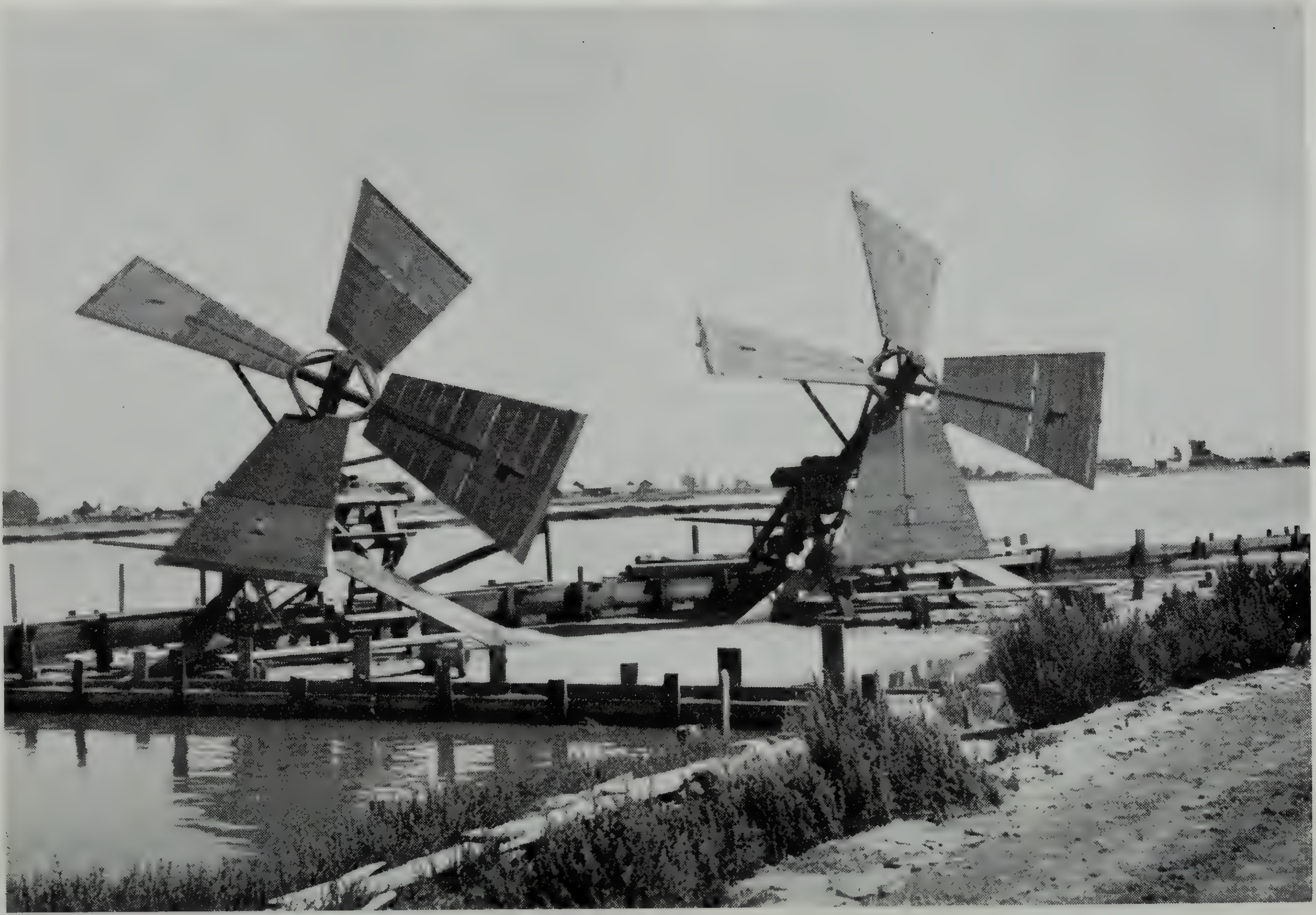
[31] Mineral resources U. S. 1929, pt. 1, p. 449.



A, SEWER PIPE PLANT
California Pottery Company, Niles, Alameda County.

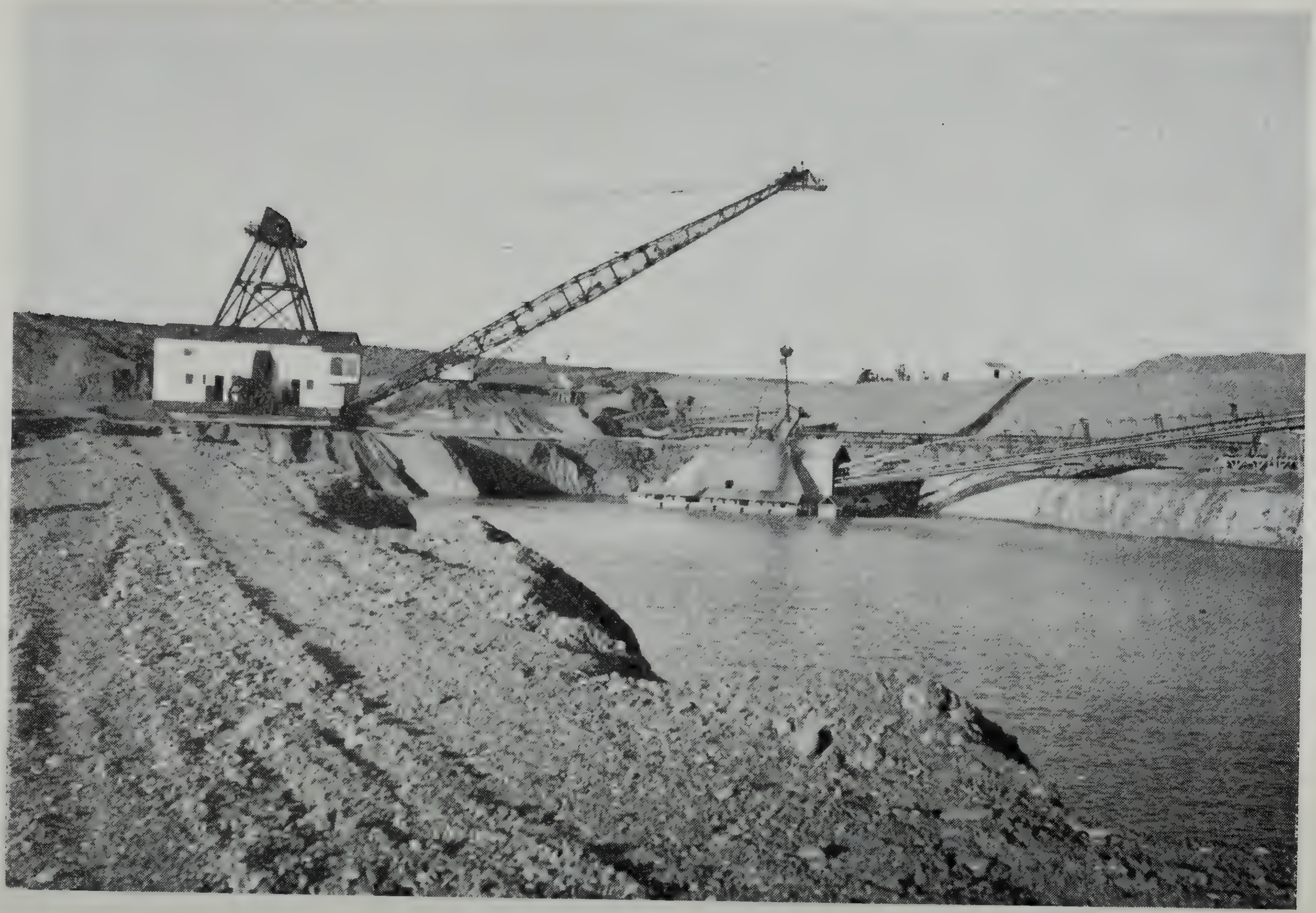


B, MAGNESIA PLANT
Westvaco Chemical Corporation, Newark, Alameda County.

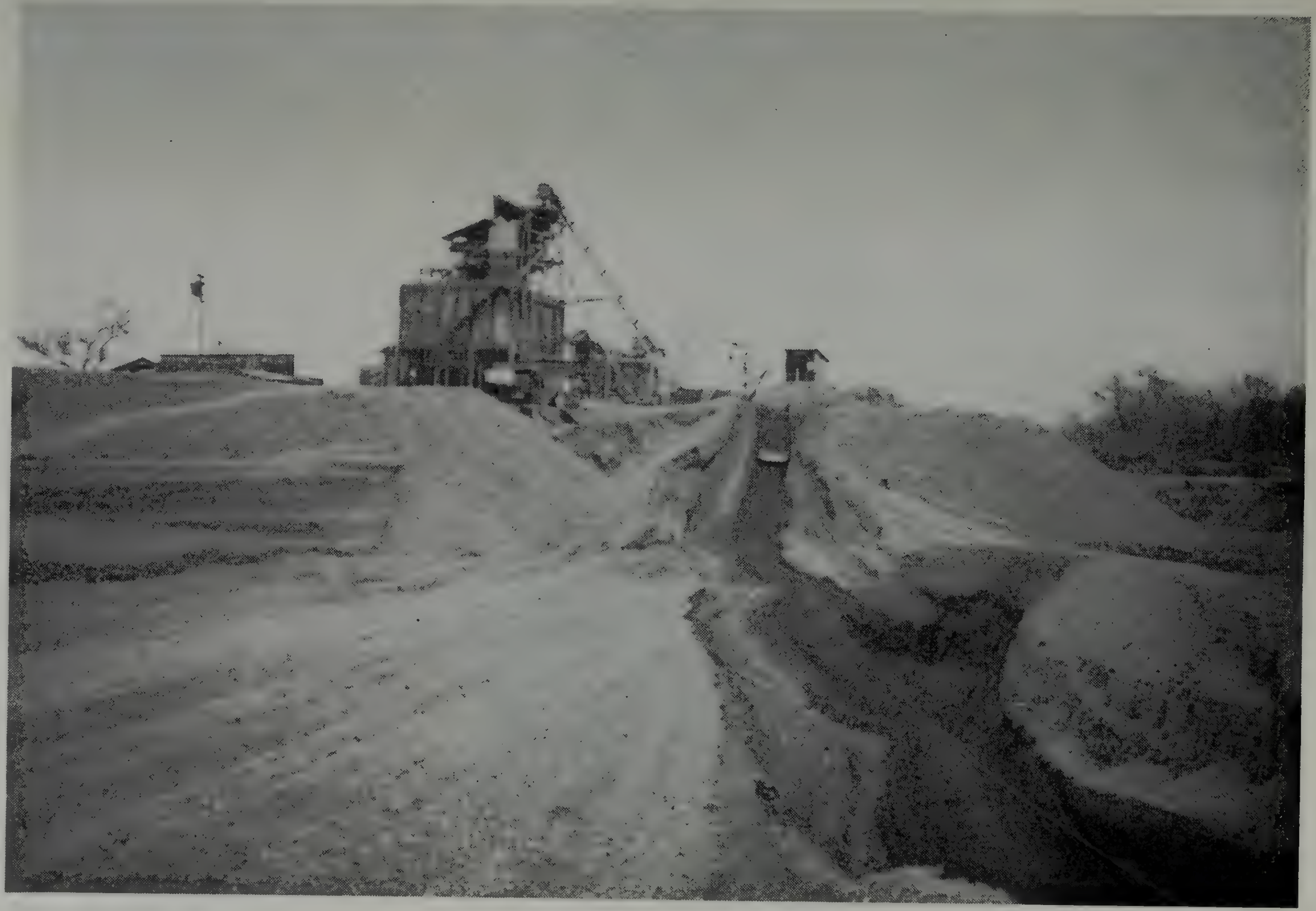


BRINE PUMPS
American Salt Company, Newark, Alameda County.

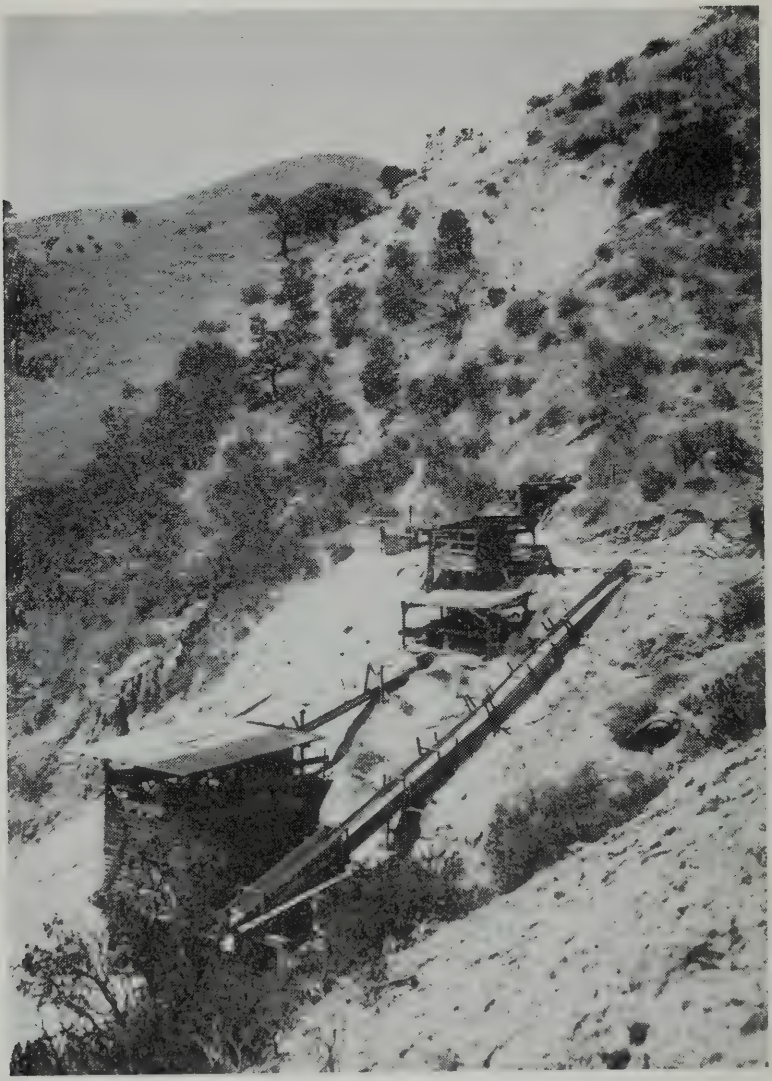
SALT HARVEST
Leslie Salt Company plant, Newark, Alameda County.



GRAVEL DRAGLINE WITH FLOATING CONVEYOR
Henry J. Kaiser Company, Radum, Alameda County.

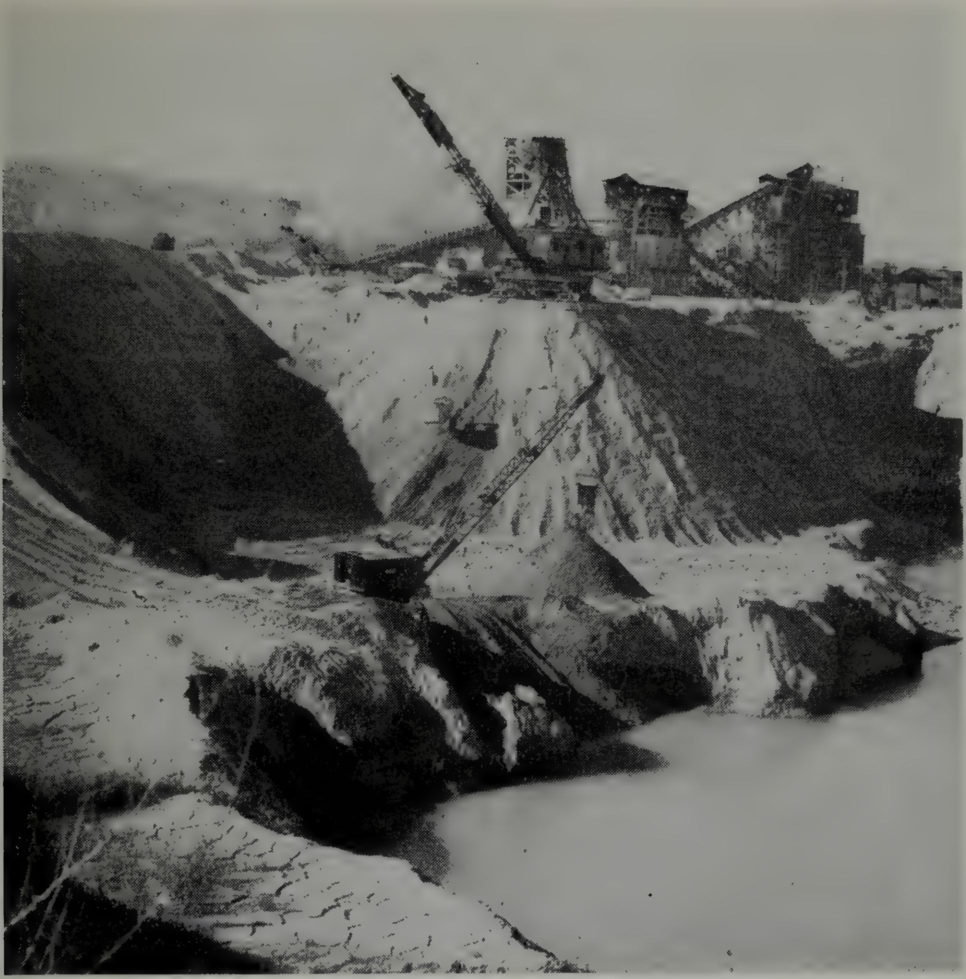


DRAG-SCRAPER GRAVEL MINING
Concrete Materials Company, Radum, Alameda County.

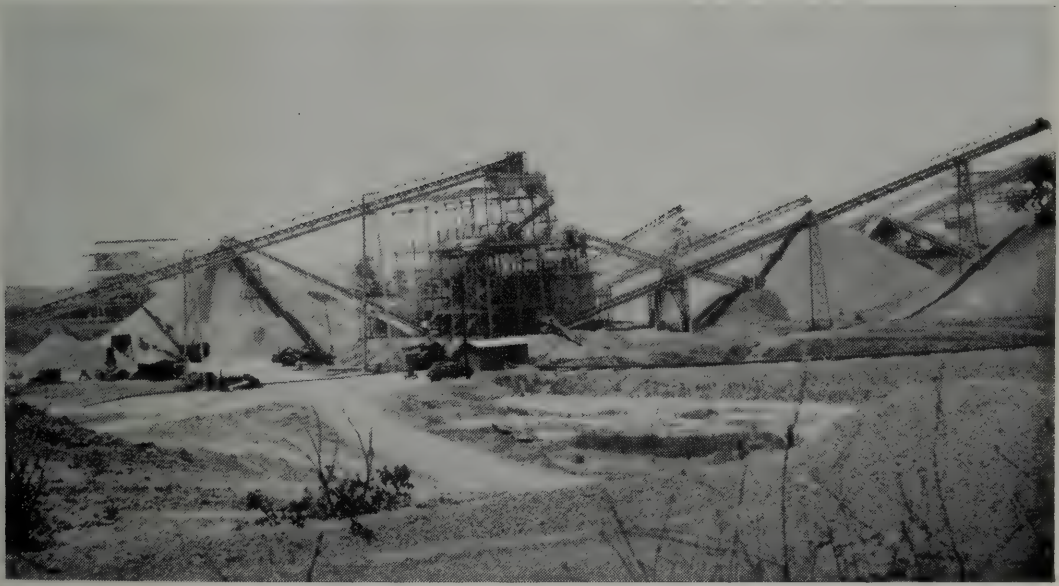


A, MOLDING-SAND MINE AND PLANT
Tesla Sand and Clay Company, Tesla, Alameda County.

B, DRAGLINES MINING GRAVEL ON THREE LEVELS
Henry J. Kaiser Company, Radum, Alameda County.



A, DRAGLINES MINING GRAVEL ON TWO LEVELS
Eliot plant No. 103, Pacific Coast Aggregates Company, Inc., Alameda County.



B, GRAVEL WASHING AND SCREENING PLANT
Eliot plant No. 104, Pacific Coast Aggregates Company, Inc., Alameda County.

A, GRAVEL MINING BY BULLDOZER AND CARRYALL
Eliot plant No. 104, Pacific Coast Aggregates Company, Inc., Alameda County.

B, ROCK QUARRY
Heafy-Moore Company, Oakland, Alameda County.

Gold

Gold has been found in some of the quartz stringers in the shales and schists of the west flank of the Berkeley Hills. Lawson[32] states that fragments of quartz containing visible free gold have been found on the slopes north of Berkeley.

An analysis of pyrite ore from the Leona Heights district showed the presence of gold to the extent of $2.50 per ton.[33] A sample of unoxidized rhyolite from the same district contained gold valued at 16 cents per ton.

Industrial Minerals

Industrial Minerals and Chemical Company (American Development Company, Limited[34]) is located at 836 Gilman Street, Berkeley. L. R. Moretti is president.

The American Development Company was organized in 1928, and was reorganized in 1933 to form the present company. It is engaged in custom milling and in supplying to the industrial trade a long list of nonmetallic minerals prepared to standard specifications. The minerals prepared and their general use are indicated in Table 7.

Table 7. General uses of industrial minerals.

Material	Uses
Barytes	Calcimine, caustic filtration, colors, enamel, glass, linoleum, paint, phonograph records, putty.
Bleaching clay	Detergents, dry cleaning fluids, insecticide dusts, gasoline, mineral oils, polishes, tallows, vegetable oils.
Bentonite	Admixtures, detergents, filtration, insecticide sprays, molding sands, oilwell drilling muds, soaps.
Calcium carbonate	Chemicals, dentifrice, foods, mild polishes, poultry feeds, putty, stucco.
Chalk	Calcimine, chemicals, foods, mild polishes, putty.
China clays	Adhesive filler, asphalt, calcimine, colors, insecticide dusts, paper, rubber.
Dolomite	Chemicals, feeds, mild abrasives.
Feldspar	Abrasives, ceramics, soaps.
Fluorspar	Ceramics, enamels, glass, flux in steel.
Marble	Flooring, roofing, acid water treatment swimming pools.
Silica, (quartz)	Ceramics, flooring, glass, refractories.
(sand)	Ceramics, glass, refractories.
(amorphous)	Dentifrice, insecticide dusts, paint.
Slate	Asphalt, records, roofing.
Soapstone	Carving, insecticide dusts, paint, rubber.
Talc	Ceramics, paint, rubber.
Volcanic ash	Abrasives, soaps, floor-cleaning compounds.
Whiting	Adhesives, calcimine, enamel, inks, linoleum, mild polishes, paint, rubber.

The crude minerals are obtained both from California deposits and from deposits outside the state. The plant contains crushers, screens, grinding mills, and equipment for gravity and air classification.

Railroad shipments of crude minerals are received on a plant spur track and are bottom-dumped to a concrete receiving hopper. The crude flows by gravity into a skip by which it is elevated vertically to a 24-inch Robinson jaw crusher at the top of the plant. The crude is reduced to 1 inch size from a maximum size of 18 inches. Stationary screens are provided to remove the fines in 6- and 8-mesh sizes. A Traylor double roll crusher is used for further reduction of the crude minerals. An 11- by 7-foot Hardinge conical pebble mill; and a 6- by 18-foot single-compartment Hendy tube mill, are available for special grinding work. Final grinding is usually done in a 5-roller Raymond mill, equipped with a 60-inch exhauster. Here pulverization takes place, and industrial-grade mineral is classified by air, and bagged. A gas furnace adjoins the lower part of the Raymond mill, which permits the simultaneous drying and grinding of ores. Minerals containing as much as 20 percent moisture can thus be prepared without separate drying.

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[32] Lawson, Andrew C., op. cit., pp. 22-23, 1914.

[33] Aubury, Lewis E., The copper resources of California: California Min. Bur. Bull. 50, p. 170, 1906.

[34] Pacific Chemical and Metallurgical Industry, February 1938.

The plant runs two 8-hour shifts on a 5-day week, and employs 15 men. It is electrically operated with 150 connected horsepower, and has a capacity of 10,000 tons per year.

Lead

Coarse crystalline galena in 100-pound lumps has been found near Euclid Avenue and Cordonices Creek in Berkeley. Lawson [35] said these lumps may have been derived from deposits in the Franciscan formation. A smelter at Melrose (East Oakland) operated by Whittier Fuller Company extracted lead from Inyo County ores in 1891-92.[36] A total of 1,362,700 pounds of lead ore was treated, and the lead was used in the manufacture of white lead. It is possible that the 1,500 pounds of lead produced in 1902 (as shown in table 4), was obtained from the slag dump of the Melrose smelter.

Lime and Limestone

Small lenses of siliceous freshwater limestone, occurring in the Orinda, Siesta, and Moraga formations (Pliocene), have been described by Lawson.[37] He also mentions small patches of travertine on the west slope of the Berkeley Hills north of Berkeley.

A small production of agricultural lime was made from a marl deposit near Mission San Jose, and from a deposit midway between Sunol and Pleasanton. These and other occurrences of limestone have been described more completely in a report by Logan.[38]

An extensive deposit of oyster shells (13) in the southern part of San Francisco Bay has supplied neighboring industrial plants with a low-cost raw material of high lime content for many years. Seaton [39] discusses the use of these shells in the production of magnesia by the Westvaco Chemical Division of Food Machinery Corporation, as follows:

> "A satisfactory source of low-cost lime is one of the key factors in any competitive operation producing magnesia values by processing a solution. The Newark district is unusually favored in regard to this critical matter in that floor of near-by San Francisco Bay is liberally coated with oyster shells. Few live oysters now exist in this district, but must once have been present in immense quantities. The shells are small and quite pure, giving a lime containing less than 0.5 percent silica, around 0.2 percent iron oxide, 0.2 percent aluminum oxide, and about 1.0 percent magnesium

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[35] Lawson, Andrew C., op. cit., 1914.

[36] Watts, W. L., Alameda County: California Min. Bur. Rept. 11, p 126, 1893.

[37] Lawson, A. C., op. cit., 1914.

[38] Logan, C. A., Limestone in California: California Jour. Mines and Geology, p. 205, 1947.

[39] Seaton, Max Y., Production and properties of commercial magnesias: Am. Inst. Min. Met. Eng. Tech. Pub. 1496, p. 12, 1942.

> oxide. They are thoroughly coated with mud, but this is soft and nonadherent and can be washed from them very readily. Recovery of shell from the Bay floor proceeds by hydraulic dredging, shell being washed with clean sea water on the dredge to a clay content of 0.1 percent or so, then pumped to transfer barges for delivery to the Newark plant. An 8000-ft. canal, terminating in the deep-water Newark slough, allows delivery of oyster shell to be made direct to the back door of this plant, so to speak.
>
> "Many unsuccessful attempts to produce a commercial lime of satisfactory quality from San Francisco Bay oyster shells are on record. Behind most of these failures was lack of recognition of the fact that to develop desirable qualities in the lime made from these shells requires the application of higher than normal lime-burning temperatures. Once this fact is recognized, and once it is conceded that a basic lining for a rotary kiln will be required at the temperatures employed, no particular difficulty is encountered in making a quicklime of excellent quality. At the Newark plant, the calcining is done in a rotary kiln 315 ft. long and 7½ ft. in diameter, followed by a proper rotary cooler and by normal mechanical handling equipment. Natural gas is employed as fuel."

Magnesite

Pockets and small diverse veins of magnesite are associated with a body of serpentine at Cedar Mountain *(15)* in sec. 27, T. 4 S., R. 3 E. No production has been reported since 1917. Float and outcrops of magnesite have also been found on Rocky Ridge in sec. 24, T. 4 S., R. 2 E. Although the demand for magnesium compounds remains high, sea-water or salt-plant bitterns now constitute the source material in California. The bitterns have replaced crude magnesite mined by underground methods. This change has occurred as a result of the greater accessibility, lower processing cost, and more uniform chemical composition of the bittern raw material. The mining of crude magnesite is not likely to be resumed, except on a small scale, unless a new large high-grade deposit is discovered. The development of magnesite properties in Alameda County has been described in detail by Bradley.[40]

Magnesium Compounds

Magnesia (MgO) and magnesium compounds made from salt-plant bitterns form an important part of the total mineral production from Alameda County. A wide variety of magnesias and periclase are produced. There has been a large demand for dead-burned magnesia refractories for use in steel furnaces. Oxychloride cement, a salt of magnesia, is used for flooring. The hydroxide is used in pharmaceutical preparations. Other compounds are used in the manufacture of rayon and for insulating materials.

Westvaco Chemical Corporation (14) (see *Bromine* for company history and bittern analysis).

Salt-plant bitterns are processed at Newark for the production of various grades of magnesia. Raw bitterns from the storage ponds (containing both magnesium sulphate and magnesium chloride), and calcium chloride from a storage tank are all fed into a cylindrical, conical-bottom, Pachuca agitating tank. Here the fluids are thoroughly mixed by compressed air introduced through a centrally located, perforated, vertical air tube. The mixture flows to a second Pachuca tank and overflows from the latter into two 55- by 12-foot Dorr thickeners in series where calcium sulphate (synthetic gypsum) is precipitated. The solution, magnesium chloride, overflows from the last thickener into a 69- by 12-foot storage tank.

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[40] Bradley, Walter W., Magnesite in California; California Min. Bur. Bull. 79, pp 40-43, 1925.

The gypsum is removed to a 6- by 6-foot Oliver filter by an Oliver-Sabin pump. It is spray-washed and filtered, dried in a Raymond cage kiln, and conveyed to concrete storage bins having a capacity of 2,000 tons. The production capacity of the plant is 150 tons of gypsum per day, most of which is used in the manufacture of portland cement.

A low-cost lime, obtained by calcining oyster shells dredged from the floor of San Francisco Bay, was formerly used to process the magnesium chloride solution. In 1946 however, the process was revised, and calcined dolomite was substituted for lime in the reaction with the magnesium chloride solution. The crude white dolomite is produced at a company quarry in La Cienega Valley near Hollister. The dolomite is crushed to minus ⅝-inch size at the quarry and shipped to Newark in 75-ton gondola cars. The cars are bottom-dumped to storage bins or unloaded by gantry crane on surface stock piles. This ore passes to a conveyor belt discharging to a water-jacketed screw feeder at the entrance to the kiln. Here the dolomite is calcined in a 7½- by 315-foot Traylor rotary-lime kiln with a capacity of 150 tons of dolomite per day. The calcined dolomite (lime-magnesia) passes from the kiln to a 5- by 50-foot return rotary cooler located in a concrete pit under the kiln. The lime-magnesia is ground in a Raymond vertical roller mill and sent to the reaction chamber where it remains for several hours in contact with the magnesium chloride solution.

The resulting brine and magnesium hydrate sludge are removed to a 12- by 55-foot Dorr separator-thickener where the insoluble sludge is settled and the brine overflows to a storage tank. The sludge is moved by Oliver-Sabin pumps through a series of five 12- by 55-foot Dorr thickeners, where it is washed free of salt and other impurities. The wash-water flow is countercurrent to that of the sludge. A soft, fresh water is obtained from wells 700 feet deep equipped with Sterling deep well pumps. The washed sludge is pumped to additive tanks and mixers where alumina, lime, iron oxide, or silica may be added, depending upon the properties desired in the final product. Ground white magnesite of relatively high silica content from the Western mine dump, ground blue-gray crystalline magnesite of relatively high lime content from Nevada, and ground silica sand (90 percent minus 200 mesh) from Monterey, are some of the raw materials added or blended with the magnesium hydrate sludge. The mixture is settled, decanted, and pumped to a pair of 8- by 12-foot Oliver drum filters where the filter cake is removed and sent to one of four rotary kilns for final burning.

Periclase, a high-temperature product containing more than 93 percent magnesium oxide, is produced in an 11- by 195-foot Traylor wet-process kiln. The kiln is fired with ''off-time'' gas and can be converted for oil-firing in 10 minutes. A temperature of about 1800° Centigrade is attained in this furnace. The kilns are equipped with dust-collecting systems whereby the recovered dust is returned and mixed with the sludge. A similar furnace is used in making seawater caustic calcined magnesia. This product is also made in a smaller 90-foot furnace. These products are discussed by Seaton [41] as follows:

> "Several different light-burned magnesias of essentially this fundamental composition are produced. They differ relatively little in chemical analysis, but quite widely in activity, the more active products, as would be suspected, having been calcined at a relatively low temperature. Save for the harder burned but still noncrystalline products, they are light, fluffy, intrinsically extremely finely divided powders, which have found wide acceptance in the fields that require magnesium oxide for making oxychloride cements or for a variety of chemical uses.
>
> "A few of the typical products produced at the Newark operation, with an outline of their chemical and physical properties, are listed in table 8, primarily to give some idea of the range of products that can be developed from the primary raw material offered by the Newark plant."

Table 8. Analyses of typical magnesia products at Newark plant (percent)

Constituent	No. 2661 (chemical magnesia)	No. 2665 (caustic magnesia)	No. 2671 (maintenance deadburn)	S-90 (seawater periclase)
Ignition loss	0.2	4.0	--------	--------
SiO_2	0.6	0.6	5.0	5.3
Fe_2O_3	0.2	0.2	6.5	0.3
Al_2O_3	0.3	0.3	1.5	0.4
CaO	1.5	1.4	4.7	1.8
MgO	97.2	93.5	82.3	92.2″

An 80-foot furnace is used in making caustic calcined magnesia from a blend of Nevada and Western mine ore. After firing, the magnesia products are cooled and conveyed to 500-ton, cone-bottomed, steel storage bins.[42] Rigid product specifications are maintained by frequent laboratory tests and samples of all shipments are retained for a year.

The daily capacity of the plant is 150 tons of dolomite, 150 tons of gypsum, and 120 tons of magnesia products. The plant operates three shifts per day and employs between 225 and 250 men.

Manganese (16-17-18)†

During World Wars I and II when imports were undependable, every manganese deposit in California was a potential source of this essential steel-making element. The following quotations are taken from a report [43] prepared by the California Division of Mines and Federal agencies, as a result of investigations undertaken during those critical periods:

> "Most of the California manganese ore is found in chert of the Franciscan formation, which is extensively exposed in the Coast Ranges. The ore in the Franciscan formation follows the bedding, and, though it has been hydrothermally altered in places, it is of sedimentary origin. Deposits of the same type are found in older cherts in the Sierra Nevada.
>
> "The most abundant primary ore mineral in the Franciscan deposits is a gray, fine-grained, nearly pure rhodochrosite, cut by widely spaced veinlets of quartz from a sixteenth to a quarter of an inch wide. The better,

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† The geology of each Alameda County deposit is described in detail in, Trask, Parker D., and others, Geologic description of the manganese deposits in California: California Div. Mines Bull. 152, pp. 15-27, in press.

[41] Seaton, Max Y., op. cit., 1942.

[42] Trauffer, W. E., Lime, gypsum and magnesia produced from sea water and shells at new plant in California: Pit and Quarry, May 1938.

[43] Jenkins, Olaf P., and others, Manganese in California: California Div. Mines Bull. 125, pp. 74, 97-101, 1943.

> more massive ore is the most likely to be found in the thicker orebodies, though there are many exceptions to this rule. Massive ore tends to maintain its character to within a few feet of the edge of the orebody, where it grades into disseminated ore, which in its oxidized form is called stockwork ore. The primary manganese mineral in the disseminated ore is chiefly a silicate, presumably bementite, though rhombs and spherules of rhodochrosite up to an eighth of an inch in diameter are embedded in the chert at the margins of some orebodies. Bementite, however—or at least some hydrous silicate of manganese—is especially characteristic of low-grade ore.
>
> "Some of the orebodies contain no massive ore but consist entirely of disseminated (Bementite?) ore. These low-grade bodies are ordinarily less than 3 feet thick. Their small size is a natural corollary of the fact that a large, rich orebody normally has a massive core surrounded by a rind in which the manganese minerals are disseminated. In the smaller bodies the rich core is lacking and only the lean rind is there."

Reference is made to the manganese deposits of Alameda County as follows:

> "Manganese is reported from about 30 localities in Alameda County. All of these, except one, are in the Arroyo Mocho Valley or adjacent territory, southeast of Livermore, and are typical Franciscan deposits in chert. The one exception is on the Dyer property in Altamont Pass, where limestone fragments partly replaced by manganese oxides are found in deep soil, of which they constitute less than 1 percent. They range up to 2 inches in length, and seem to be derived from a Cretaceous conglomerate. They contain about 30 percent manganese.
>
> "The Arroyo Mocho Valley has been an important source of manganese, having yielded 4,600 tons from 16 properties. The principal mines have been the Camp 9, the Man Ridge, the Section 14, the Taylor-Pitcher, the Bartlett, the Graves, the Black Jack, the Nelson or Bailey, and the Corral Hollow. No production has been reported during the present war, and only a few deposits are now being prospected. The Man Ridge, the Nelson or Bailey, and the Section 14 are the only deposits visited that were found to have been worked recently."

Manganese ore has been produced intermittently in the county from 1894 to 1922. The largest annual production was made during 1918 when peak World War I prices were paid. There was no production from 1923-41 inclusive. Table 9 shows the county's record of production during World War II (recalculated to a basis of 45 percent manganese content).

During the early part of World War II ores containing a minimum of 35 percent manganese were purchased by Metals Reserve Company for the government stock pile. A 42 percent manganese content was required of ores shipped after December 31, 1944, consequently many mines ceased operating.

Mineral Paint

Mineral paints are natural minerals used as pigments. Most of them consist of impure mixtures of iron oxides and clay, and are classed under the term ''ochers.'' A gradational series of iron minerals occur in nature, as indicated in table 10.

Since most deposits of mineral paint consist of a combination of these minerals, a considerable variation of color may be expected within a deposit. This condition, and the ''pockety'' nature of the deposits has

Table 9. Manganese production in Alameda County during World War II.

Year	Long tons	Value
1942	49	$1,374
1943	76	3,062
1944	178	6,542
1945	7	318
Totals	310	$11,296

resulted in the gradual replacement of natural-mineral pigments by synthetic pigments. Uniformity of color and quantity of production can be more carefully controlled in the manufacture of synthetic pigments.

A small quantity of mineral paint, the result of deposition from an iron spring, has been produced by C. K. Williams and Company, Emeryville, from the vicinity of the Alma pyrite mine.[44] This material was hand-shoveled to trucks and the deposit was soon exhausted.

Mineral Springs

Numerous mineral springs exist in Alameda County, and they have been described by Anderson, Waring, and Laizure.[45] No commercial production of mineral water has been reported.

Table 10. Variation in composition and color of iron oxide.

Mineral	Formula	Iron content (percent)	Water content (percent)	Color
Limonite	$2Fe_2O_3.3H_2O$	40	60	Yellow
Goethite	$Fe_2O_3.H_2O$	50	50	Yellow-brown
Turgite	$2Fe_2O_3.H_2O$	66⅔	33⅓	Reddish-brown
Hematite	Fe_2O_3	100	0	Red

Petroleum (19)

The Diablo Range, extending about 200 miles southeastward from Carquinez Strait, is a dominant topographic and structural feature in the southern Coast Ranges of California. It flanks the San Joaquin Valley on the west, and its northern end culminates in Mt. Diablo in central Contra Costa County. Numerous minor structural features such as anticlines, synclines, and faults, have been mapped throughout the area of the Tesla [46] quadrangle, where the Diablo Range traverses eastern

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[44] Symons, Henry H., Mineral paint materials in California: California Div. Mines Rept. 26, p. 152, 1930.

[45] Anderson, Winslow, Mineral springs and health resorts of California, p. 223, 1892. Waring, Gerald A., Mineral springs of California: U. S. Geol. Survey Bull. 338, 1915.
Laizure, C. McK, Alameda County: California Div. Mines Rept. 25, pp. 437-439, 1929.

[46] Anderson, Robert, and Pack, Robert W., Geology and oil resources of the west border of the San Joaquin Valley north of Coalinga, California: U. S. Geol. Survey, Bull. 603, 1915.
Huey, Arthur S., op. cit., pp. 64, 66, 1948.

Table 11. Data sheet on wells drilled for oil in Alameda County, 1900-48.

T	R	Sec.	Location	Company	Year drilled (D) or abandoned (A)	Depth feet	Bottom hole formation	Remarks
2S	1W	19		Elsinore Oil Co. of Nevada No. 1	1925(D)-1926(A)	630	Miocene (?)	
2S	2E	22		Alameda Oil Co. of San Francisco		1175		
2S	2E	26	SW¼ of NW¼	?	1895±	1100	Miocene (?)	Gas at 600 ft.
2S	3W	30	2850′ W and 1350′ S of NE cor.	Frederich Libby, Lavagnetto No. 1	1940(D)-1942(A)	885		No production.
2S	3E	7	4180′ N and 4200′ W of SE cor.	Shell Oil Co. Inc., Nissen No. 1	1941(D)-1942(A)	6563		No production.
2S	3E	20	NE¼	Standard Oil Co., Egan No. 1	1908(D)-1909(A)	1090	Panoche	No showings.
2S	3E	27	NE¼	Standard Oil Co., Leonardo No. 1	1908(D)-1909(A)	2878	Panoche	Oil show 1275.
2S	4E	19	165′ S and 1000′ W of NE cor.	Burney Syndicate No. 1	-1934(A)	1200	Monterey	
3S	1W	29	300′ S and 300′ E from NW cor. of Woods ranch	Hayward Oil Co. Ltd., No. 1	-1932(A)	708	Cretaceous	
3S	3E	6	675′ S of N line and 2075′ E of NW cor. of property	Atlantic & Western Oil Co. No. 1				
3S	3E	6		Atlantic & Western Oil Co. No. 2	pre 1925(A)	200(?)	Cretaceous	
3S	3E	7	1890′ N and 50′ E of SW cor.	Bradford & Guardino, B&G No. 1	1945(D)-1945(A)	500±		Oil emulsion 250
3S	3E	9	900′ N and 1100′ W of SE cor.	James E. Coniff, Calhoma Oil Corp., No. 1	1926(D-)1929(A)	1523	Monterey or Panoche	
3S	3E	13	330′ N and 160′ E of W/4 cor.	Seaboard Oil Corp., Johnston No. 1	1936(D)-1936(A)	5925	Panoche	Few gas shows.
3S	3E	14	600′ N and 500′ E of W/4 cor.	George L. Craig No. 1A	1926(D)-1927(A)	1602		Oil and gas show 800.
3S	3E	15	Near SW cor.	Doane No. 1	pre 1900			
3S	3E	15	1500′ N and 3500′ E of SW cor.	Independence Oil Co.	1911(D)-1912(A)	1700	Cretaceous	Oil and gas shows.
3S	3E	15	1500′ N and 3500′ E of SW cor.	Atlantic & Western Oil Co., French No. 1	1921(D)-1933(A)	3150		Drilled to 1700 by Ind. Oil Co..
3S	3E	15	1500′ N and 1000′ E of SW cor.	Alisal Oil Co.	1909(D)-1910(A)	979	Panoche	60 ft. oil sand at 544′. Pumped 5-10 B/D fluid; 30° oil, 75% water.
3S	3E	15	2000′ N and 1500′ E of SW cor.	W. M. & S. Co., Hamilton Ranch No. 1	1910(D)-	450		Oil shows.
3S	3E	15	1800′ S and 1100′ E of NW cor.	W. M. & S. Co., Hamilton Ranch No. 2	1912(D)-	600	Cretaceous	Oil shows.
3S	3E	15	2250′ S and 1076′ W of NE cor.	A. M. Gilstrap No. 1	1931(D)-1933(A)	1335		Gas show 1065, oil show 1270.
3S	3E	15	1400′ N and 500′ E of SW cor.	15-3 Oil Co., Hamilton Ranch No. 1	1900±	600-800		Lost tools.
3S	3E	15	2600′ E and 400′ N of SW cor.	15-3 Oil Co., Hamilton Ranch No. 2	1900±	1200-1400		Oil shows 640.
3S	3E	15	500′ N and 250′ E of SW cor.	Talbot Oil Co., No. 1	1926(D)-1927(A)	510		
3S	3E	15	1000′ N and 500′ E of SW cor.	Livermore Valley Oil Co., 1A	1921(D)-1923(A)	612		Oil shows 515-608; 15-20 B/D oil before water broke in.
3S	3E	16	25′ N and 900′ W of SE cor.	Thomas & Hammill No. 1	1926(D)-1928(A)	1025	Cretaceous (?)	Oil show 801.
3S	3E	21	150′ S and 450′ W of NE cor.	Foster & Hammill No. 2	1928(D)-1929(A)	1570		Oil and gas shows.
3S	3E	25	Near center		pre 1915	1800		No showings.

References: California Div. Mines Bulletins 118 and 140; U. S. Geol. Survey Bulletin 603; California Div. Oil and Gas records.

Alameda County. The surface outcrops in the northern half of the Tesla quadrangle consist of rocks of Cretaceous and Tertiary age, exposed in undulating hills ranging from 500 to 2,000 feet in elevation.

The occurrence of petroleum in this part of Alameda County was noted as early as 1868.[47] The oil seepages at the Hamilton ranch in SW¼ sec. 15, T. 3 S., R. 3 E., on the south flank of the Patterson Pass anticline, were described by Anderson and Pack,[48] who stated that the oil occurred in the lower part of undifferentiated middle or upper Miocene sandstone. They believed that the oil had migrated ''from underlying Cretaceous beds exposed in this area, or from younger Cretaceous or lower Tertiary strata lying farther south.'' Huey [49] stated that oil-water emulsions were obtained at shallow depths from water wells drilled in sec. 7, T. 3 S., R. 3 E. The broad Altamont anticline extends southeastward for more than 3 miles through secs. 27, 28, 34, and 35, in T. 2 S., R. 3 E. Sandstone, shale, and clay of the Panoche formation (Upper Cretaceous) are exposed along the axis of this fold.

The petroleum possibilities in the Tesla district were summarized by Anderson and Pack [50] as follows:

> ". . . it may be said that the probability of obtaining a large quantity of oil in the Tesla district is remote, but that wells producing a little light-gravity oil may possibly be obtained in very small areas. Such wells may derive their oil either from sandy beds in the Cretaceous or from the lower beds of the unconformably overlying Tertiary, the latter offering the better chances."

Approximately 25 wells have been drilled for oil in the Tesla quadrangle. ''Showings'' of oil and gas were reported from many of these wells. Two wells are rumored to have produced a few barrels of oil, although the California Division of Oil and Gas has no record of such production. Early in 1949 the Hancock Oil Company began leasing acreage in this area. Some of the land covered by the leases is included in T. 2 S., R. 2 E., T. 3 S., R. 2 E., and T. 3 S., R. 3 E.

Potash

Prior to World War I there had been no production of potash (K_2O) in California. With the outbreak of war and the cessation of potash importing from Germany, it became imperative that all potential domestic sources of supply be developed. The residual bitterns from the salts plants of Alameda County contain about 6 percent potassium chloride. This mineral was recovered from the bitterns by the Oliver Chemical Company, division of Oliver Salt Company, from 1917-21, and from 1924-27. The final product contained a K_2O equivalent of 12 to 45 percent [51] There has been no production of potassium salts from these brines since 1927.

Pyrite

Beginning about 1891 and extending through 1934, Alameda County has an almost continuous record as a producer of pyrite, FeS_2. Rhyolite outcrops as a narrow belt along the west flank of the Berkeley Hills, from Berkeley to Decoto. These outcrops attain a maximum width of about 1½ miles in the vicinity of Leona Heights, sec. 2, T. 2 S., R. 3 W. Here the rhyolite is a compact rock and fresh surfaces exhibit a pale blue-green color and small disseminated crystals of cubic pyrite. Apatite, $(CaF)Ca_4(PO_4)_3$, magnetite, Fe_3O_4, and zircon, $ZrSiO_4$, were found as accessory minerals, by Clark [52] in a microscopic study of the rhyolite. Extensive weathering, however, has caused oxidation of the pyrite to mixtures of yellow-brown limonite and red hematite. It was this bright-colored gossan which first attracted the attention of the miners, who mined it for mineral paint. The pyrite ore bodies were encountered as the depth of mining increased.

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[47] Irelan, Wm., Jr., Alameda County: California Min. Bur. Rept. 8, p. 25, 1888. Crawford, J. J., Alameda County: California Min. Bur. Rept. 13, p. 570, 1896.
[48] Anderson, Robert, and Pack, Robert W., op. cit., pp. 136, 187-194, 1915.
[49] Huey, Arthur S., op cit., p. 67, 1948.
[50] Anderson, Robert, and Pack, Robert W., op. cit., p. 193, 1915.
[51] Hicks, W. B., Potash: Mineral resources U. S., 1918, pt. 2, pp. 405, 427, 1918.

The ore bodies consisted of a series of lenses of massive pyrite in rhyolite. The geology of the deposits has been discussed by a number of geologists. [53] Mulryan states that small veins of both chalcopyrite, $CuFeS_2$, and bornite, Cu_5FeS_4, were encountered; chalcocite, Cu_2S, was found as earthy ore; and occurrences of sphalerite, ZnS, were noted. Mulryan also states that blue pisanite, $(FeCu)SO_4{\cdot}7H_2O$, and greenish-blue chalcanthite, $CuSO_4{\cdot}5H_2O$, were the most abundant secondary minerals. The latter mineral, and epsomite, $MgSO_4{\cdot}7H_2O$, were found as coatings on the mine timbers. Pale-green melanterite, $FeSO_4{\cdot}7H_2O$, formed crusts and stalactites from dripping mine waters. Alunogen, $Al_2(SO_4)_3{\cdot}16H_2O$, was found as a coating on the ore bunkers at the Alma mine.

Two commercial pyrite mines were developed in the area. The Alma mine, (20) sec. 34, T. 1 S., R. 3 W., was opened in 1891. The strike of the ore body was northwest, and its width ranged from 12 to 18 feet. It was developed by more than 5,000 feet of tunnels and drifts,[54] and was operated almost continuously until 1921 by the Stauffer Chemical Company, 624 California Street, San Francisco. The ore was used by the company in the manufacture of sulfuric acid at their Stege, Contra Costa County, plant. In this process the ore was roasted to drive off the sulfur-dioxide gas which was collected for acid manufacture. The remaining sinter was then leached to recover its copper and silver content. The mine was permanently closed in 1921.

The Leona mine (21) sec. 3, T. 2 S., R. 3 W., was opened about 1895. The strike of the ore body was northwest, the dip northeast. The ore body ranged in width from 18 to 30 feet, and it was developed by more than 3,000 feet of workings.[55] This mine was worked by the Leona Chemical Company until 1934, when it was permanently closed. The ore was sold to the Stauffer Chemical Company for the manufacture of sulfuric acid.

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[52] Clark, Clifton W., Geology and ore deposits of the Leona rhyolite: Univ. California Dept. Geol. Sci. Bull., vol. 10, pp. 361-382, 1917.

[53] Mace, C. H., Geology of the Leona Heights ore deposits: Min. and Eng. World, vol. 35, p. 1320, 1911.

Whitman, A. R., The vadose synthesis of pyrite: Econ. Geology, vol. 8, pp. 455-468, 1913.

Lawson, Andrew C., op. cit., 1914.

Clark, C. W., op cit., 1917.

Mulryan, Henry, Geology and ores of the Leona Heights pyrite deposit: Stanford Univ. Master's Thesis, 1925.

[54] Aubury, Lewis E., The copper resources of California: California Min. Bur. Bull. 50, p. 169, 1908.

Huguenin, E., and Castello, W. O., Alameda County: California Min. Bur. Rept. 17, p. 33, 1920.

[55] Huguenin, E., and Castello, W. O., op. cit., 1920.

Laizure, C. McK, op. cit., 1929.

Table 12. Typical analysis of ore from the Leona pyrite mine.

Mineral	Percent	Dollars per ton	Ounces per ton
Sulfur	47.78		
Iron	40.90		
Copper	1.7		
Silica plus insoluble	6.1		
Gold		0.80	
Silver			0.53

The character of the ores at these mines made extraction a consistently difficult task. The pyrite ore bodies were easily oxidized when exposed to the atmosphere in the workings, and sulfur dioxide gas was formed. The heat generated in this process often caused spontaneous combustion, and resulted in temporary closing of the mines. Workings were then sealed off to prevent access of air to the ore bodies, whereupon the fire would burn itself out. Upon reopening the mine it was usually discovered that the timbers (used in square-set mining) had burned and much of the area had caved. These recurrent mishaps resulted in expensive clean-out and re-timbering jobs, and increased the cost of mining ore to such an extent that eventually they were partly responsible for the permanent closing of the mines.

Since the closing of the Leona mine in 1934, the residential section of the City of Oakland has gradually encroached on the mining area. A subdivision embracing about 100 homes has recently been completed on a terrace within half a mile of the old workings.

Quicksilver (Mercury)

An occurrence of cinnabar, HgS, has been described by Lawson [56] as follows:

> "On the west slope of the Berkeley Hills, north of Berkeley, cinnabar has been found in a silicified rhyolite fault breccia that outcrops as a prominent knob. Assays of samples taken from the outcrop showed that the rock contains 0.5 percent of quicksilver. On the slopes below this, however, loose fragments of much richer ore have been found. No attempt has been made to prospect the deposit."

No commercial production of quicksilver has been made from Alameda County.

Salt

Inlets, which overflowed into natural marshland reservoirs at high tide, were the source of solar salt gathered by native Californians on the southeastern shores of San Francisco Bay in 1848 and 1849.[57] The salt in these basins was soon exhausted and immediate attempts were made to duplicate the processes of nature. The crude plants of the early day producers made a salt of inferior grade, which apparently satisfied the need of the consumers. In a short time, however, salt from the local plants was forced to compete with an imported product of higher quality, and thus the seeds of improvement in equipment and methods of production were sown. An impetus to bay salt production was provided by the discovery of silver on the Comstock Lode in 1859. Large quantities of salt were required in the silver reduction process; a scarcity developed, and San Francisco salt commanded a price of $35 per ton from Nevada metallurgical plants.

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[56] Lawson, Andrew C., op. cit., 1914.

[57] Hanks, Henry G., On the occurrence of salt in California and its manufacture: California Min. Bur. Rept. 2, p. 218, 1882.

By 1868, seventeen salt companies had established themselves over a 15-mile stretch between San Leandro Creek and Centerville, and 17,000 tons of salt were being produced annually. A list of 31 salt companies was reported by Bailey [58] in 1902. By this time an elaborate system of dikes and ponds had been developed, and board floors had been installed in many of the ponds. The period from 1900-20 was one of combination and consolidation of producing companies to secure more favorable marketing conditions. Out of this period the Leslie Salt Company emerged as the dominant figure in the salt industry of this area.

American Salt Company [59] *(22)* is located approximately in sec. 25, T. 3 S., R. 3 W., M.D., at the end of Depot Road, Mt. Eden. Operator is A. F. Marsicano of Mt. Eden.

This company was founded in 1865 and now holds a moderate-sized acreage of intake, crystallizing, and concentrating ponds. After withdrawal of the brine the salt layer is recovered by a modern caterpillar-mounted harvesting machine which traverses the salt surface. The harvester discharges to a train of five 2-ton steel side-dump cars hauled by a Plymouth gasoline locomotive. The train runs on portable steel tracks laid on the salt surface, and three sets of cars are in use. The crystallizing ponds are situated close to the washing plant, consequently the haul is very short.

Salt from the cars is side-dumped to a concrete receiving pit about 6 by 12 feet in size set with a grizzly of steel rails about 18 inches apart. When accurately spotted, two cars may be dumped at one stop. In this reclaiming pit the clay is removed from the salt. The contents of the pit, consisting of salt and brine, are then pumped to a wooden washing trough about 5 by 15 by 4 feet in size. A drag-conveyor about 25 feet long transfers the salt to the second wooden trough, where the final washing is effected. On emerging from the final wash-tank the salt is given a fresh-water spray to remove the adhering brine. A drag-conveyor about 50 feet long, inclined at an angle of about 50°, recovers the salt from the final wash-tank and transfers it to a horizontal belt conveyor about 50 feet long, which discharges to the coarse stock pile. The belt conveyor can be equipped with extensions to accommodate the growing stock pile.

Withdrawals from the stock pile are made as required to build up a supply of sized salt. This is accomplished by a horizontal belt conveyor-loader mounted on a mobile steel frame which is pivoted at one end. At the fixed end the belt delivers coarse salt to a vertical bucket elevator. The elevator raises the salt about 75 feet to the screenhouse where it is ground by a corrugated roll crusher, sized, and passed to the underlying bunkers for truck-loading or sacking. The salt is sacked for railroad shipment. Three grades of salt are produced at this plant: coarse, half-ground, and three-quarter ground. The plant includes a carpenter shop and a machine shop. It is electrically operated and employs 12 to 15 men during the harvesting season.

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[58] Bailey, Gilbert E., The saline deposits of California: California Min. Bur. Bull. 24, pp. 110-114, 1902.

[59] Laizure, C. McK, op. cit., p. 443, 1929.
Huguenin, E., and Castello, W. O., op. cit., p. 33, 1920.

Leslie Salt Company (Leslie-California Salt Company, Arden Salt Company, Oliver Salt Company, Leslie Salt Refining Company, California Salt Company, Continental Salt and Chemical Company) (23) plant office is located approximately in the NE¼ sec. 12, T. 5 S., R. 2 W., M. D., on Central Avenue, 3 miles southwest of Centerville, 1 mile southeast of Newark. Officers are Fred B. Bain, president, 310 Sansome Street, San Francisco, and J. C. Buchen, vice-president and production manager, Newark.

The earliest reports of the State Mineralogist[60] record the activities at the predecessor plants of the California Salt Company, and the Oliver Salt Company. On May 29, 1924, the Leslie-California Salt Company, was incorporated in Delaware as a consolidation of Leslie Salt Refining Company, California Salt Company, and Continental Salt and Chemical Company.[61] In March 1931 the Leslie-California Salt Company acquired the entire business of the Oliver Salt Company. At that time the refinery was located at Alvarado. On November 2, 1936, the Leslie Salt Company was incorporated in Delaware as a consolidation of Leslie-California Salt Company and Arden Salt Company. An issue of 350,000 shares of $10 par common stock was authorized, of which 291,300 shares were outstanding in 1948. The stock is listed on the San Francisco Stock Exchange and was quoted at $31½ per share on March 1, 1949. An average dividend of $1.95 per share has been paid every year since 1936. Moody[62] states that the new company owned about 40,000 acres of salt ponds and potential salt areas in Alameda, Santa Clara, and San Mateo Counties. In 1941 the company completed a new mill plant and refinery near Newark at the cost of $1,000,000. Some of the equipment at Alvarado was moved to the new plant. A wet salt processing plant was added to the Newark facilities and placed in operation in 1948. In addition, new salt crystallizing areas at Newark and Mt. Eden went into production for the first time in the fall of 1948. Salt-crystallizing ponds and crude salt stock piles are located at Alviso, Newark, and Mt. Eden. All processing and refining of crude salt is done at the main plant at Newark in Alameda County.

Theoretically, the production of salt from sea water is a simple process. The sea water is trapped in ponds and is evaporated by the sun and wind, leaving a residue of salt. The successful application of solar evaporation on a commercial scale requires the existence of such favorable factors as a consistently high annual evaporation rate, a relatively low annual precipitation rate, extensive low use-value tidelands, and adjacent markets. These favorable factors are combined in the marshlands fringing the south end of San Francisco Bay where rainfall averages 14 inches per year and total evaporation averages 51 inches per year.

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[60] Laizure, C. McK, op. cit., pp. 442-445, 1929.
Huguenin, E., and Castello, W. O., op. cit., pp. 33-36, 1921.
Crawford, J. J., Thirteenth report of the State Mineralogist: California Min. Bur., Rept. 13, pp. 644-645 ; 1896.
Irelan, W. Jr., Eighth report of the State Mineralogist: California Min. Bur. Rept. 8, pp. 30-32, 1888.
Hanks, H. G., op. cit., pp. 217-226, 1882.

[61] Industrial Securities: Moody's Manual of Investment, pp. 889, 3122, 1935.

[62] Industrial Securities: Moody's Manual of Investment, p. 812, 1948.

Sea water is drawn into the receiving ponds through automatic intake gates during the period of high tide extending from April to October (depending upon the rainfall during the particular year). The total mineral content of the sea water is at a maximum during this period, averaging about 3½ percent. About 2¾ percent of the total is sodium chloride (salt); the remainder consists of magnesium chloride, magnesium sulphate, calcium sulphate, potassium chloride, calcium carbonate, and bromides. Sea water has a density of 3.53° Baumé. The intake gates of wood or iron are placed in north- or northwest-facing levees to take advantage of the driving force of the prevailing northwesterly winds. Wooden gates treated with creosote are more resistant to corrosion, although they are not as water-tight as the iron gates.

The concentrating ponds are constructed in a series of 10 or 12 units which range in size from 20 to 50 acres. The amount of pumping between ponds is governed by the contour of the marshlands and every effort is made, therefore, to utilize the force of gravity flow between ponds wherever possible. The shape of the concentrating ponds exhibits considerable irregularity depending upon the distribution of the sloughs. No attempt is made to cross sloughs when ponds and levees are constructed because of the softness of the slough bottoms. It is sometimes necessary to construct boundaries of sheet-piling along ponds bordering the sloughs. The concentrating ponds, therefore, often present a meandering outline. The ratio of concentrating ponds to crystallizing ponds is about 10 to 1. The crystallizing ponds are placed inland from the sloughs and are rectangular in shape to permit easy harvesting. Since the movement of the ''pickel'' into the crystallizing ponds and subsequent removal of the brine must be made as quickly as possible, these ponds are filled and emptied by pumping. In the process of moving such huge quantities of water from the bay to the crystallizers, large low-head Byron-Jackson pumps ranging in capacity from 8,000 to 15,000 gallons per minute are used.

Floating clamshell dredges are used to build up the levees surrounding the ponds. The levees are built in stages with settling intervals of as much as 18 months intervening. The dimensions of a typical completed levee are: width of base 30 to 50 feet, width of top 12 to 15 feet, height 3 feet. Since subsidence continues after construction is completed, retopping of the levee may be required periodically. According to Buchen [63] the soil is a dense clay. All irregularities such as natural ditches are filled to the level of the surrounding marsh and any grass present is removed. The bottom is scraped and rolled smooth. It slopes toward the drain gates to permit easy removal of the bittern. The clay soil is rendered impervious to the dense brines only after 7 years of continuous flooding, and as much as 15 years are often required to place an area in full production. The natural precipitation of calcium sulphate is required to gradually close the minute pores and seal the bottoms. The levees facing the bay are also subject to erosion and must be faced with stone or reinforced on the seaward side.

As the salt water progresses through the concentrating ponds the concentration of its mineral content increases as a result of solar evaporation until a density of 20° Baumé is reached.[64] During the slow progress fine crystals of calcium carbonate, magnesium carbonate, iron carbonate, and calcium sulphate are continually formed. At 20° Baumé the concentrated brine is transferred to intermediate or lime ponds where calcium sulphate is deposited in large quantities. Here, through continued solar evaporation, the density of the brines increases to about 26¼° Baumé. Since sodium chloride begins to crystallize out of solution at a density of about 25° Baumé, a small quantity of salt is formed in the lime ponds. This salt is redissolved when weaker solutions are introduced into these ponds. At 26¼° Baumé the saturated salt solution or "pickle" is pumped into the crystallizing ponds where further solar evaporation causes deposition of the sodium chloride. As the salt deposition continues more "pickle" is pumped into the crystallizers and this procedure continues until the brine in the crystallizing ponds attains a density of 29¾° Baumé. By this time the concentration of the brine has reached the point where undesirable components such as magnesium chloride begin to crystallize. Since the bottom of the crystallizing ponds are sloped toward the drain gates, the bittern or concentrated solution which remains is pumped out and transported by pipeline to a neighboring chemical company. Fresh "pickle" is again added to the crystallizer and the entire process is repeated until a layer of salt (sodium chloride) 4 to 6 inches thick has been deposited on the bottom of the crystallizing pond. The salt, which is very pure, becomes a mass of intergrown cubic crystals, which attain a considerable size. A cluster of such crystals on display in the museum of the California Division of Mines, Ferry Building, San Francisco, exhibits crystal units measuring 2 inches on an edge.

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[63] Buchen, Joseph C., Evaporating salt from the world's largest mineral deposit: Mining and Metallurgy, pp. 335-338, July 1937.

The harvesting of the salt crop has evolved through many stages and the item worthy of note in each successive stage is the constantly decreasing dependence of the operation upon manual labor. In the early days salt was hand-shoveled to wheelbarrows, later to dump carts in the ponds, and still later to pond conveyors. The modern method utilizes a caterpillar-mounted harvesting machine. In this machine revolving picks break up the salt and deliver it to a belt conveyor which loads a waiting train of bottom-dump cars at the rate of 125 tons per hour.[65] The train consists of 12 to 14 wooden cars of 2-ton capacity, hauled by a 4-ton Vulcan gasoline engine running on a portable 24-inch gauge track. Once begun, harvesting the salt crop continues incessantly until completed. Three shifts of 8 hours each, requiring three 9-man crews, are worked daily. Artificial lighting is used at night.

The salt is hauled to a central washing plant where the moving cars are bottom-dumped to a subsurface longitudinal receiving tank containing sea water. Here the salt is scrubbed thoroughly to remove entrained clay, calcium sulphate crystals, and occluded bittern. After cleaning, the salt is elevated by two Byron-Jackson centrifugal pumps (capacity 175 tons per hour) to the dewatering screws. The latter consists of a twin screw classifier 24 inches by 20 feet. The brine is returned to the wash tank and the salt passes by chute to two steel log washers, 24 inches by 20 feet, where the final traces of impurities are removed. The salt passes by chute to an inclined dewatering drag about 10 feet wide and 100 feet long. The drag bottom is perforated so that the excess brine may drain off, and the salt is carried to the top. En route it receives a final fresh-water spray; then it is delivered to a horizontal belt conveyor mounted on the top of a steel trestle 50 feet high. The trestle and belt are about 600 feet long and are equipped with right- and left-hand stacking belts, each about 100 feet long. Two stock piles of crude salt over 99 percent pure, totaling about 500,000 tons, are thus built up. Although a hard protective surface crust soon forms, winter rains reduce the size of the stock pile by about 10 percent.

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[64] See, D. S., The salt industry: Paper presented at Pacific Chemical Exposition, San Francisco, p. 3, October 1947.

[65] Buchen, Joseph C., Salt: Pacific Factory, p. 52, July 1948.

Crude salt may be reclaimed from the storage pile and sent to the processing plant where it is prepared for additional uses. Working atop the pile of crude salt, caterpillar diesel D-6 bulldozers push the salt toward chutes strategically located along its periphery. In this way salt is moved through the chutes to short lateral inclined belt conveyors at the rate of 150 tons per hour. The lateral conveyors feed a horizontal main line belt about 600 feet long installed in the base of the trestle near ground level. The first transfer point is placed at the end of the trestle where a right-angle change in direction is effected and a cross conveyor belt carries the crude salt load for about 200 feet. A second right-angle transfer is then made, and the salt resumes its original course on a third belt. The third belt is about 600 feet long. The first half of the belt is horizontal and the second half is inclined to permit delivery of salt to receiving bins on the top floor of the wet processing plant.

As previously mentioned, the processing plant is new and was placed in operation in February 1948. It has a rated handling capacity of 2,400 tons per day.

From the receiving bins crude salt may be withdrawn for (1) loading directly into gondola cars in bulk quantities of 55 to 58 tons; suction loading is provided for box cars which handle about 40 tons; these railroad cars are shipped to chemical plants where about 60 percent of the crude production is consumed; (2) rewashing in brine, draining, partial drying, screening, sizing, and bagging for truck shipment; four Richardson automatic scale loaders fill sacks of 125-pound capacity; (3) rewashing, chemical treatment, draining, and conveyance by tunnel belt to the adjoining refinery where about 27 percent of the crude output is refined or semi-refined.

The refinery, operating since 1941, makes a semi-refined or kiln-dried crude and a pure vacuum-grade product. In making the kiln-dried product wet salt from the processing plant is delivered to a horizontal gas-fired counter-current rotary hot-air dryer, where organic matter and moisture are eliminated at a temperature of 365° Fahrenheit. Butane is used as a fuel during the winter season when the demand for natural gas is at its peak. A short bucket-elevator transfers the salt from the dryer to a rotary cooler. After cooling the salt moves by bucket-elevator to the crushing room, passes through Allis-Chalmers crushing rolls, is sized on Hummer screens, and falls to storage bins. Salt dust from the rolls is removed by blowers to one of two 1,000-pound hydraulic presses. These presses make 50-pound rainproof salt blocks for stock feeding purposes. The salt is withdrawn as required from the storage bins through hoppers by automatic-weighing rail-mounted packaging machines. It is packed in paper, cotton, or burlap bags and sold to the meat- and fish-packing industries. This salt is 99.8 percent pure and represents about 15 percent of the crude salt production.

The vacuum process of salt making is based upon the physical fact that the boiling point of a solution varies directly as the pressure on its surface. By reducing the pressure in the evaporators the boiling temperature required to crystallize pure salt from solution is reduced. The resultant substantial savings in the cost of fuel for steam production makes the vacuum-evaporation process the most economical known method of salt-making. Pure vacuum-evaporated refined salt is made from rewashed crude. Wet salt from the processing plant is dissolved in distilled water. The saturated salt solution is treated with sodium carbonate (soda ash), aerated to precipitate any impurities, and sent to the triple-effect (a set of three) evaporating pans. The typical evaporating pan is described by See [66] as follows:

> "26 ft. high by 11 ft. in diameter, coned at the bottom and slightly so at top, with a steam belt in the lower half which contains some 900 copper tubes, 5 ft. long by 2¼ inches in diameter. Propeller agitation is supplied from under the belt forcing circulation of the brine up through the tubes. Brine feed is continuous and controlled to hold a definite level of liquid in each pan, according to its evaporating rate. Salt is continuously crystallizing, dropping to the bottom because of gravity, and being removed along with some liquid brine. It may be removed either by pump against its vacuum head, or by gravity through a barometric leg."

Live steam from the steam generating plant is introduced into the first evaporator through the steam belt. The steam circulates around the copper tubes causing the brine to boil violently. Boiling is effected at a lower temperature than would result in an open pan because some air has been removed by pumping to create a partial vacuum. Hot-steam vapors from the boiling brine are withdrawn through a vent in the top of the first evaporator and flow to the steam belt of the second evaporator. Since more air is withdrawn from the second evaporator it operates at a higher vacuum and its brine boils at a further reduced temperature. The highest vacuum is maintained in the third evaporator which operates on hot vapors withdrawn from the second evaporator. Here a final temperature of only 140° Fahrenheit is required to produce boiling as contrasted with a temperature of 226° Fahrenheit required in an open vessel at atmospheric pressure.

See [67] continues:

> "The salt and brine mixture is discharged into a cone tank, where it is brine washed by countercurrent coil, removed by pump which elevates it, along with some of the brine as a carrier, to a second cone tank, where it receives another countercurrent wash with fresh clean brine, and is then fed to an Oliver Filter for separation of the brine and preliminary drying. It is then conveyed to a hot air rotary dryer, discharging at a temperature of 365° F, and removing all but a few hundredths per cent of moisture. Then, through rotary cooler and into storage bins. From storage bins it goes through hummer vibrating screens which separate it into various grades, according to particle size, and discharge to packing bins, from where it is packed into the various shipping containers. This salt is very pure, averaging 99.90% NaCl, or better, on a dry basis."

About 12 percent of the crude output is consumed in the production of vacuum grade salt.

Natural gas is the fuel used in the steam-generating plant, which includes one Kewanee and two Babson and Wilcox boilers. Electricity

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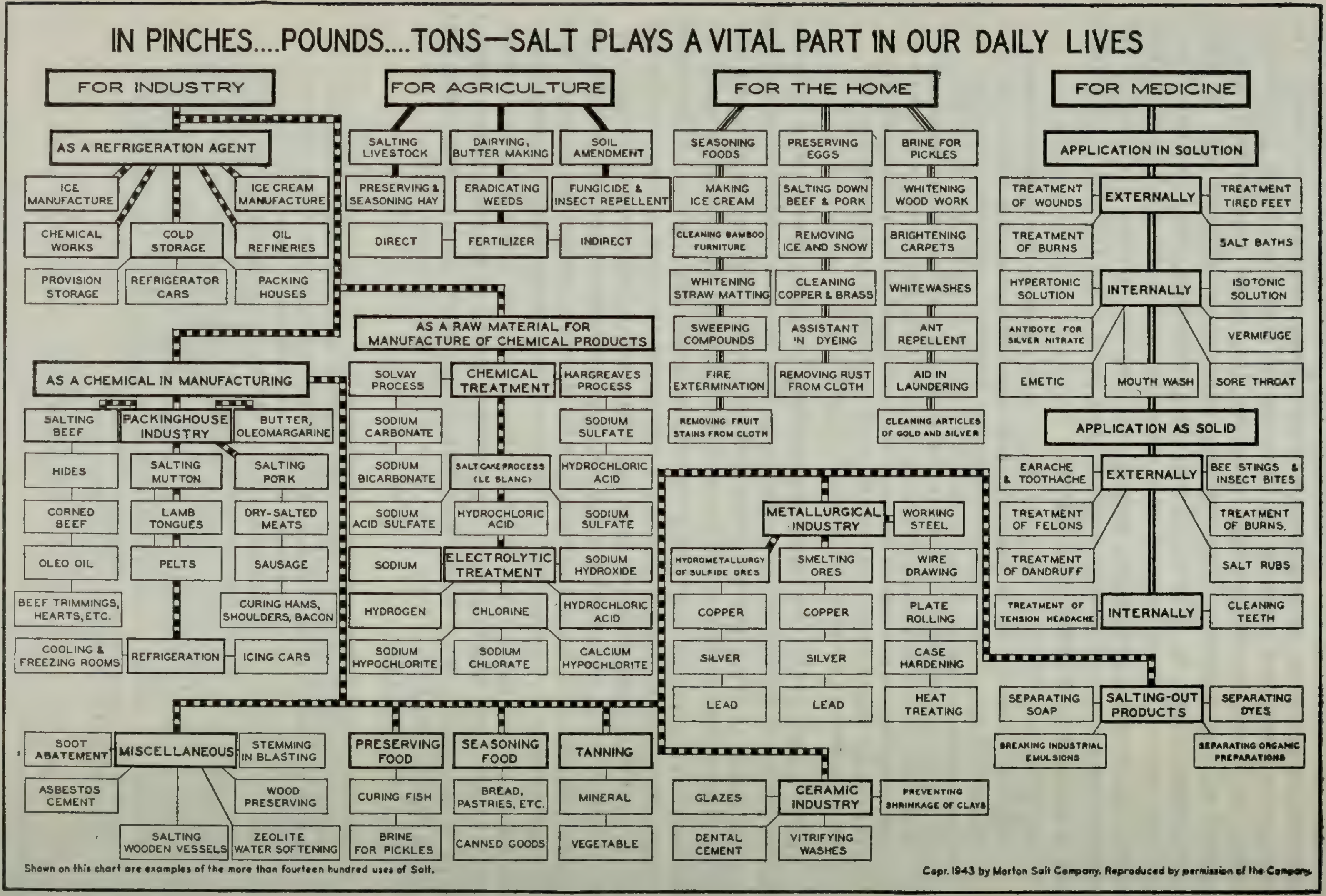
[66] See, D. S., op. cit., p. 5, 1947.
[67] See, D. S., op. cit., p. 5, 1947.


IN PINCHES....POUNDS....TONS—SALT PLAYS A VITAL PART IN OUR DAILY LIVES
FOR INDUSTRY
AS A REFRIGERATION AGENT
ICE MANUFACTURE
ICE CREAM MANUFACTURE
CHEMICAL WORKS
COLD STORAGE
OIL REFINERIES
PROVISION STORAGE
REFRIGERATOR CARS
PACKING HOUSES
AS A CHEMICAL IN MANUFACTURING
SALTING BEEF
PACKINGHOUSE INDUSTRY
BUTTER, OLEOMARGARINE
HIDES
SALTING MUTTON
SALTING PORK
CORNED BEEF
LAMB TONGUES
DRY-SALTED MEATS
OLEO OIL
PELTS
SAUSAGE
BEEF TRIMMINGS, HEARTS, ETC.
CURING HAMS, SHOULDERS, BACON
COOLING & FREEZING ROOMS
REFRIGERATION
ICING CARS
SOOT ABATEMENT
MISCELLANEOUS
STEMMING IN BLASTING
ASBESTOS CEMENT
WOOD PRESERVING
SALTING WOODEN VESSELS
ZEOLITE WATER SOFTENING
FOR AGRICULTURE
SALTING LIVESTOCK
DAIRYING, BUTTER MAKING
SOIL AMENDMENT
PRESERVING & SEASONING HAY
ERADICATING WEEDS
FUNGICIDE & INSECT REPELLENT
DIRECT
FERTILIZER
INDIRECT
AS A RAW MATERIAL FOR MANUFACTURE OF CHEMICAL PRODUCTS
SOLVAY PROCESS
CHEMICAL TREATMENT
HARGREAVES PROCESS
SODIUM CARBONATE
SODIUM SULFATE
SODIUM BICARBONATE
SALT CAKE PROCESS (LE BLANC)
HYDROCHLORIC ACID
SODIUM ACID SULFATE
HYDROCHLORIC ACID
SODIUM SULFATE
SODIUM
ELECTROLYTIC TREATMENT
SODIUM HYDROXIDE
HYDROGEN
CHLORINE
HYDROCHLORIC ACID
SODIUM HYPOCHLORITE
SODIUM CHLORATE
CALCIUM HYPOCHLORITE
PRESERVING FOOD
CURING FISH
BRINE FOR PICKLES
SEASONING FOOD
BREAD, PASTRIES, ETC.
CANNED GOODS
TANNING
MINERAL
VEGETABLE
FOR THE HOME
SEASONING FOODS
PRESERVING EGGS
BRINE FOR PICKLES
MAKING ICE CREAM
SALTING DOWN BEEF & PORK
WHITENING WOOD WORK
CLEANING BAMBOO FURNITURE
REMOVING ICE AND SNOW
BRIGHTENING CARPETS
WHITENING STRAW MATTING
CLEANING COPPER & BRASS
WHITEWASHES
SWEEPING COMPOUNDS
ASSISTANT IN DYEING
ANT REPELLENT
FIRE EXTERMINATION
REMOVING RUST FROM CLOTH
AID IN LAUNDERING
REMOVING FRUIT STAINS FROM CLOTH
CLEANING ARTICLES OF GOLD AND SILVER
METALLURGICAL INDUSTRY
WORKING STEEL
HYDROMETALLURGY OF SULFIDE ORES
SMELTING ORES
WIRE DRAWING
COPPER
COPPER
PLATE ROLLING
SILVER
SILVER
CASE HARDENING
LEAD
LEAD
HEAT TREATING
GLAZES
CERAMIC INDUSTRY
PREVENTING SHRINKAGE OF CLAYS
DENTAL CEMENT
VITRIFYING WASHES
FOR MEDICINE
APPLICATION IN SOLUTION
TREATMENT OF WOUNDS
EXTERNALLY
TREATMENT TIRED FEET
TREATMENT OF BURNS
SALT BATHS
HYPERTONIC SOLUTION
INTERNALLY
ISOTONIC SOLUTION
ANTIDOTE FOR SILVER NITRATE
VERMIFUGE
EMETIC
MOUTH WASH
SORE THROAT
APPLICATION AS SOLID
EARACHE & TOOTHACHE
EXTERNALLY
BEE STINGS & INSECT BITES
TREATMENT OF FELONS
TREATMENT OF BURNS.
TREATMENT OF DANDRUFF
SALT RUBS
TREATMENT OF TENSION HEADACHE
INTERNALLY
CLEANING TEETH
SEPARATING SOAP
SALTING-OUT PRODUCTS
SEPARATING DYES
BREAKING INDUSTRIAL EMULSIONS
SEPARATING ORGANIC PREPARATIONS

Shown on this chart are examples of the more than fourteen hundred uses of Salt.

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FIGURE 1. Chart showing some of the 1400 uses of salt.

is the source of power and two Diesel-electric generators have been installed as standby power units.

Morton Salt Company[68] *(24)* plant office is located approximately in the NE¼ sec. 12, T. 5 S., R. 2 W., M. D., on Central Avenue, 3¼ miles southwest of Centerville, 1 miles southeast of Newark. Officers are Daniel Peterkin Jr., president, 208 West Washington Street, Chicago, Illinois, and C. W. Lesser, plant manager, Newark, California.

The Newark refinery of the Morton Salt Company was constructed in 1926 for the production of vacuum-refined and kiln-dried salt in numerous forms. Crude salt was originally purchased from the Arden Salt Company. In 1936 the latter producer was absorbed by the Leslie Salt Company, from whose adjoining stock piles all subsequent requirements of crude salt have been obtained. The crude salt is washed and dissolved to make a concentrated raw brine which is transferred to the treatment tanks. Here, slight impurities in the form of magnesium chloride are removed by the addition of sodium hydroxide. The sodium is replaced by the magnesium, the latter is precipitated as magnesium hydroxide, and the sodium reinforces the content of the brine. The magnesium hydroxide is discarded and the purified brine is pumped to two 100,000-gallon storage tanks 16 feet high and 30 feet in diameter. The brine is metered to the triple-effect evaporators, 10 feet by 40 feet, where the pure salt is crystallized. Salt is removed from the evaporating pans as a slurry with a moisture content of 23 percent. It is pumped to a slurry storage tank, and withdrawn to an 8-foot Robison top-feed filter. After filtering the moisture content drops to 2 percent. A gas-fired, horizontal dryer, 5 feet 6 inches by 33 feet in size, operates at a temperature of 350° Fahrenheit and reduces the moisture content to less than one-tenth of 1 percent. After passing through a rotary cooler 5 feet 6 inches by 33 feet, the salt is elevated to a 5- by 15-foot, 4-deck, monel metal Rotex screen where numerous products are separated and discharged to monel metal storage bins. Some of the size ranges of vacuum salt are as follows: Coarse, minus 28 to 34 mesh; table, minus 34 to 72 mesh; flour, minus 72 mesh; and butter, minus 48 to 72 mesh. Steam for the evaporators at a pressure of 125 pounds per square inch is provided by three 285-horsepower Sterling boilers.

Kiln-dried salt is produced from washed crude salt by passing it through a gas-fired rotary kiln, cooling it in a rotary cooler, elevating it to four Allis-Chalmers crushing rolls, and screening the product on eight three-deck Hummer screens.

The sacking and packaging[69] of salt is an extremely mechanized series of operations. The salt is automatically weighed, dropped into a loading spout, and discharged to each sack; the sacks are conveyed to high-speed sewing machines which close the tops. Cartons are loaded in a similar manner. They are machine made at the plant and consist of two layers of fibreboard separated by a layer of asphaltum. Labels are automatically applied to the empty cartons which are then coated with a moisture-proof lacquer and dried under a bank of 50 infra-red lamps.

Salt has many uses. As indicated in the accompanying chart (fig. 1), more than 1,400 have been recorded. It is an essential raw material in the soap, paper, steel, oil, tanning, mining, textile, stock-raising, packing, dairy, baking, and chemical industries. In addition, salt is widely used in the medical profession and in the home.

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[68] Laizure, C. McK, op. cit., pp. 445-447, 1929.
[69] The History of Salt, Morton Salt Company.

Oliver Bros. Salt Company (25) is located approximately in sec. 31, T. 3 S., R. 2 W., M. D., about 2 miles southwest of Mt. Eden on the San Mateo bridge road. Owners are A. E. Oliver, and A. A. Oliver Jr., of Mt. Eden.

This property was acquired in 1937 and the production of salt began in 1938. It consists of 160 acres of intake, concentrating, and crystallizing ponds. At harvest time the brine is drained from the crystallizing ponds and the layer of salt is hand-shoveled in slabs about one foot square to a scoopmobile type loader. The loader moves on a 2-inch wooden mat, about 10 feet wide, which is made up in squares and laid on top of the salt layer. It dumps to a mobile field storage bin located at the side of the pond. A short conveyor-loader transfers the crude salt from the bin to 2½-ton dump trucks which transport it to the washing plant on the highway.

Here the salt is dumped into a rectangular recovery trough about 10 feet long. Any clay adhering to the bottom of the salt is washed out and a horizontal drag-conveyor removes the salt to a washing screw. The rewashed salt is then passed through a set of grinding rolls where it is reduced to a maximum size of 1¼ inches and returned to a second washing screw. It then passes to a short wooden washing trough, and is removed by an inclined drag-conveyor to a third rectangular wooden trough where the final washing is made. On emerging from this trough the salt receives a fresh-water spray to remove the pickle. An inclined drag-conveyor about 40 feet long elevates the clean salt and delivers it to a horizontal conveyor for stock piling.

Perforated tracks on the inclined conveyors assist in drawing off the excess moisture and return the fine salt crystals to a 40-foot inclined screw conveyor. The latter delivers the fine crystals to a distributing belt which carries them to the three-quarter-ground stock pile inside an adjoining warehouse. Three grades of salt are produced at this plant, namely: coarse-ground, plus ⅝-inch to minus 1¼-inch; half-ground, plus ⅛-inch to minus ⅝-inch; and three-quarter-ground, minus ⅛-inch.

This salt is sacked in 125-pound sacks and sold in carload lots f.o.b. plant warehouse. In November 1948 prices ranged from $9 to $10 per ton, depending on the grade. The plant is electrically operated and five to eight men are employed. There is no present market for the brines from this plant.

Silica (Molding Sand)

The use of sands from California deposits by the foundry industry of the state is summarized by Wright,[70] who states:

> "The state-wide foundry industry of California, with its substantial production of iron, steel, and non-ferrous metal castings, has, since its inception, drawn heavily on sands produced in the state. Consequently, the growth of a modest, but increasingly important foundry-sand industry has paralleled that of the foundries themselves. At present, the yearly production of California foundry sands is in the neighborhood of 90,000 tons. This tonnage is divided between clay-free sands and naturally bonded sands in the approximate ratio of three to two."

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[70] Wright, Lauren A., California foundry sands: California Jour. Mines and Geology, vol. 44, pp. 37-72, 1948.

Tesla Sand and Clay Company[71] (Ryan Ranch Clay Deposit) *(26)* is located in parts of secs. 25 and 26, T. 3 S., R. 3 E., M.D. Operator is G. G. Sanders, Mills Building, San Francisco; marketing agency is Brumley-Donaldson Company, 557 Howard Street, San Francisco.

A white bed of high-silica sandstone containing 31 percent clay is mined in the steep hills on the north side of Corral Hollow near the west end of the latter. This bed is a member of the Tesla formation described by Huey[72] and is about 15 feet thick. The bed strikes about N. 70° W. and dips 60° NE. The outcrop has been traced more than a mile northwestward and about a quarter of a mile southeastward along the strike from the mine openings. The latter are located about 250 feet above the level of the Hollow at an elevation of 1,250 feet.

The southeast workings are opened by a 5- by 10-foot adit. This adit is irregularly timbered with 6-inch sets at a minimum spacing of 5 feet. It is more than 300 feet long and contains narrow-gage rails. The northwest workings are opened by a short crosscut and a drift along the bed for a distance of 200 to 250 feet. The drift is timbered with 6- by 6-foot posts and caps and 14-inch narrow-gage rails are laid to the face. The sandstone is friable and breaks readily when shot down with 45 percent Hercules gelamite. Small end-dump cars are used for hand tramming. A portable diesel-compressor supplies air to the face of the drift through a flexible 6-inch ventitube line. Lighting is supplied by a portable diesel-electric generator. Mining activities are carried on in the northwest workings on an intermittent basis depending on the demand of the foundries which use the sand.

The rock is broken to minus 6-inch size in the mine and hand-trammed to bin at the entrance to the workings. Here the minus ¼-inch fines are removed by an 18- by 36-inch screen. The oversize passes through a Cruendler pulverizer powered by a caterpillar-30 engine and the crushed rock is discharged to an inclined semi-circular steel chute about 45 feet long. The crusher-run material is about minus 1-inch in size. The gravity flow of crushed rock along the chute to the two storage bunkers is augmented by vibrations supplied from a four-cylinder engine mounted on top of the bunkers. The latter have a capacity of about 75 tons each. The crushed material may be trucked either to consumers or to a railroad siding at Livermore located about 12½ miles west of the mine.

According to Wright[73] this natural mixture of sand and fire-clay is known to foundrymen as ''Livermore ganister'' and is used as a refractory in ladle patching and furnace linings. He states that the sand grains range from 50 to 200 mesh, and that the average fusion cone of selected samples was 29+, or 2,984° Fahrenheit. The following quotation is from his article:

> "Livermore 'Ganister' is being widely used in synthetic facings for medium and heavy iron work . . . The sand is fine enough—A.F.A. 99—so that its addition to facing mixtures does not affect the finish, while the fact that the sand is high in silica makes it desirable from the refractory standpoint.
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> "The clay in the Livermore 'Ganister' is exceedingly refractory . . . Unfortunately, the Livermore 'Ganister' is too high in clay to be used

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[71] Huey, A. S., op. cit., p. 60, 1948.
Wright, Lauren A., op. cit., pp. 48-50, 1948.
Laizure, C. McK, op. cit., p. 432, 1929.
Dietrich, Waldemar Fenn, op. cit., pp. 42-45, 1928.
[72] Huey, Arthur S., op. cit., pp. 33-38, 1948.
[73] Wright, Lauren A., op. cit., p. 48, 1948.

> straight as a molding sand . . . (and) it is blended with sharp sands and milled . . . In using Livermore 'Ganister' in place of fire clay in facings, the heaps do not lose permeability as fast because of the quartz sand in the material . . ."

Stone Industry

Alameda County ranked first among the 58 counties of the state in annual value of ''miscellaneous stone'' production, from 1943-45 inclusive. The county ranked second in annual value of ''miscellaneous stone'' production during 1946-47. ''Miscellaneous stone'' is a term used to include crushed rock, sand and gravel, paving blocks, and grinding-mill pebbles. This usage has developed from the fact that an individual operator often produces sand and gravel from a stream bed, using the large boulders as the source of his crushed material. Crushed rock is often further subdivided on a usage basis into macadam, ballast, rubble, riprap, and concrete aggregate, although it is not always possible to determine the final disposition of the product. The production of miscellaneous stone from the county has exceeded $1,000,000 in annual value every year since 1935, and has exceeded $3,000,000 in annual value every year since 1941. An all-time high was reached in 1944 when miscellaneous stone valued at $6,112,065 was produced in the county. In the same year, Alameda County ranked ninth in total value of all annual mineral production by counties of the state.

During the past 30 years (1920-49), Alameda County has consistently ranked eighteenth or higher in total value of all annual mineral production by counties of the State. This high position in the list of 58 counties has resulted in a large measure from the extensive development of the stone industry in the county. During this period the use of dimension stone (quarried blocks) in buildings has gradually been replaced by concrete, owing chiefly to the lower labor costs involved. Thus there has been an intensified demand for the materials of concrete construction, namely crushed rock, sand, and gravel. A wide variety of crushed rock is used commercially depending on the kind available in the district. The rocks giving most satisfactory service are metamorphosed sandstones, chert, basalts, and other hard dense igneous rocks which break with sharp, clean edges. Alameda County, situated close to a large center of population and industrial activity, has been in a particularly favorable position to supply these raw materials from the rock formations within her confines.

Chert and metamorphosed Franciscan sandstone, obtained along the west flank of the Berkeley Hills, from Berkeley to Niles, have been the source of much of the crushed rock. At these quarries the bank-run material is shovel-loaded to trucks, transported to crushing plants on the premises, reduced and sized. Some of the crushed-rock products are washed, although washing is not required on road and fill material.[74] Sand and gravel are obtained from extensive deposits in the Livermore Valley and on the Niles alluvial cone. Where sand and gravel are excavated from stream beds, the pits thus formed may be refilled by winter flood waters. The soft easily decomposed rocks are pounded, pulverized and washed away as mud, leaving only the harder, more resistant materials. The gravel is transported by trucks or belt-conveyor systems to nearby washing and screening plants. Here, the pit-run gravel is washed, screened, and graded to sizes suitable for concrete aggregate.

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[74] Standard specifications, California Dept. Public Works, Div. Highways, 1945.

The ratio of sand and gravel production to crushed rock production in the county was 3.46 to 1 in 1947.[75] Sand and gravel produced totaled 3,844,057 short tons valued at $3,578,314, while crushed rock produced totaled 1,112,500 short tons valued at $714,025. The average value for each ton of sand and gravel produced was 93 cents, compared with 64 cents for each ton of crushed rock. This difference results from the fact that sand and gravel (especially for concrete aggregate) is in most cases a more highly processed material. The average production per man per hour in the sand and gravel plants of the California area [76] was 5.4 tons.

The rapid shift of population and industry to the San Francisco Bay area, as well as to other parts of California since 1940, has resulted in an expanded building program and an intensified demand for materials of construction. Concrete highways, buildings, dams, aqueducts, and canals, require enormous quantities of sand, gravel, and crushed rock for aggregate. As long as this type of construction continues, operations in the stone industry will remain at a high level.

Ashland Rock and Material Company (27) is located approximately in the E½ sec. 5, T. 3 S., R. 2 W., M.D. (projected), about half a mile north of Foothill Boulevard, between 164th and 165th Avenues. Operator is Cliff Mankins, 7735 San Leandro Street, Oakland, who leases the property from the Sorenson Equipment Company.

This is a small quarry about 4 years old. The quarry face is about 50 feet high and semicircular in shape, and contains some serpentine near the west end. A small amount of overburden is removed before blasting. The rock is blasted down and loaded by a 1½-yard P and H caterpillar mounted shovel. Trucks haul about 200 feet to a Universal portable crushing plant powered by an Allis Chalmers motor. The rock is dumped to a 5- by 10-foot grizzly with 12-inch openings. It passes down a 20-foot chute to a jaw crusher 12 by 18 inches in size, then to a conveyor belt about 30 feet long which loads the rock directly to trucks. The ''crusher run'' material can be elevated 30 feet to a 3- by 10-foot trommel making 1½-inch and oversize of 2½-inch, which is discharged to two small bins.

Bell Sand and Gravel (28) property is located in the NW¼ sec. 2, T. 5 S., R. 1 W., M.D. (projected), on Durham road about half a mile south of the Mission road, Irvington. Owner is C. A. Bell, Box 282, Irvington, who acquired the plant in January 1947. It has been in operation for about 10 years.

The property consists of about 34 acres and includes one hill in a low front range of hills extending out into the alluvial plain. This hill is about 125 feet high ranging from an elevation of 75 feet at the base to 200 feet at the top. While the presence of gravel has been tested to a depth of 75 feet below road level at the base of the hill, the actual depth is no doubt many times greater, as it represents accumulation on the alluvial plain itself.

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[75] Averill, Charles V., and others, The counties of California: California Div. Mines Bull. 142, pp. 29-32, 1949.

[76] Gwinn, G. Richards, and Tucker, G. E., Sand and gravel: Minerals Yearbook, pp. 1047-1064, 1946.

Josephson, G. W., and Jensen, Nan C., Stone: Minerals Yearbook, pp. 1102-1134, 1946.

The topographic map of the Pleasanton quadrangle shows that the trend of the front range is northwestward. It is about 10 miles long and varies in width from about half a mile near the southern end to nearly 2 miles at the northern end. The Geologic Map of California indicates the gravels are of Pliocene-Quaternary age, similar to the lower gravels of the Livermore Valley. The northern end of the range appears to represent the alluvial cone of a Pliocene-Quaternary stream which discharged from the mountains in a northwestward direction. Subsequent relative movement along the Hayward fault or the Calaveras fault has changed the direction of stream flow, resulting in the present dissection of the alluvial cone by the westward-flowing streams.

The gravel is unconsolidated and is worked with a caterpillar diesel bulldozer. The material is removed in a series of parallel cuts and carried by the bulldozer to a surge pile at the west side of the hill. The surge pile overlies a 6- by 7-foot concrete conveyor-loading tunnel, with overhead manually operated feed gates. The conveyor is about 250 feet long and elevates the gravel to a receiving hopper overlying a three-deck Diamond vibrating screen where wash water is introduced. Fines may be separated either by a Bodinson drag classifier or a trommel classifier. The finished products consisting of 1½-inch, ¾-inch, ⅜-inch, and minus ⅜-inch, are delivered to three 200-ton gravel and two 90-ton sand bunkers. All bunkers are truck loading. A ¾-cubic yard Wagner scoopmobile is used for loading trucks from ground stock piles.

Horsepower used in the plant is distributed as follows: conveyor feeder 5, conveyor belt 30, screen 20, drag classifier 7, and water pump 30; totaling 92 connected horsepower. Water for the plant is provided by a well 240 feet deep and is delivered in a 6-inch line. Five men are employed and production is about 400 tons per 8-hour day.

Buranis Brothers and Company (29) property is located in the S½ sec. 16, T. 3 S., R. 2 E., M. D. (projected), on Arroyo Mocho about 1 mile south of Livermore on the Arroyo Road.

Buranis Brothers, Livermore contractors, own 35 acres along the Arroyo Mocho. During World War II the U. S. Government stripped about 3 feet of surface material and then removed about 20,000 cubic yards of gravel which was used locally in army and navy installations. The gravel was mined with a steam shovel, delivered to a bin feeding a 100-foot bucket elevator, and run through a trommel which separated sand, pea gravel, ¾-inch rock, 1¼-inch rock, and oversize. The screening plant remains on the property.

California Rock and Gravel Company (30) is located in sec. 24, T. 3 S., R. 1 E., M. D. (projected), about 2 miles west of Livermore and 1 mile south of the highway. Officers are F. N. Woods, president; F. W. Erlin, executive vice president and general manager; J. S. Silva, plant superintendent. The address is 1800 Hobart Building, San Francisco.

The property consists of 250 acres along the course of the Arroyo Valle which flows northwestward in this vicinity. The surface is covered with an overburden which may be as much as 10 feet deep. Exploratory wells have determined the presence of gravel to a depth of 120 feet, although present excavations are usually terminated at about 90 feet. The gravel varies from sand to boulders 12 inches in diameter with occasional fragments of larger size. A typical screen analysis of the gravel shows about 35 percent passing a ⅜-inch screen, with about 80 percent passing a 3-inch screen.

The pit-run gravel is excavated by an electrically operated, walker-mounted, completely revolving, Monighan dragline, equipped with a 3-yard front-discharging bucket. The dragline advances the walls of the pit by making two cuts of 45 feet each. When stripping overburden, the latter is removed by the same equipment and deposited on the pit floor previously excavated. The gravel is dumped to a mobile steel truck-loading field bunker of 50 tons capacity.

A point of interest on the field bunker is the installation of a company designed ''knocker'' to dislodge wet material which has a tendency to hang up and retard discharge when loading the trucks. This ''knocker'' is a small structural-steel truss with one short and one long leg resembling an isosceles triangle. The truss is hinged to the bunker side at the apex of the two legs, the long leg being in contact with the upper part of the bunker. A rope attached to the upper end reaches the ground for manual operation as needed. A snap of the rope brings the lower leg of the truss against the bunker, loosening any material stuck to the inside. The ''knocker'' is returned to its normal position by gravity accompanied by an additional shaking effect.

The field bunker empties into 20-ton bottom-dump Euclid trucks which haul about a quarter of a mile to a road grizzly passing minus 10-inch material to the receiving hopper at the plant. A reciprocating feeder delivers the contents of the hopper to a 24-inch conveyor belt, 185 feet long, which terminates at the primary scrubber. This scrubber is a 6- by 20-foot steel cylinder set with its long axis in a horizontal plane normal to the feed belt. It revolves at a rate of about 12 revolutions per minute. The cascading effect and recurrent impact of the gravel against the cylinder frees the pebbles from the fines and bonding material. The lower or discharge end of the scrubber is fitted with a 7-foot conical screen that flares outward, and a large volume of water is introduced here to facilitate screening. The screen is made of punched steel plate with circular openings. The openings are 1¼ and 3¼ inches respectively. Three products are separated at this point. The minus 1¼-inch passes to two side launders feeding a Wemco screw classifier 78 inches in diameter and 30 feet long; the 1¼- to 3¼-inch passes to the mill conveyor belt; the plus 3¼-inch oversize is rejected by the screen to the head of a 13-inch Allis-Chalmers gyratory crusher, set in the floor of the supporting structure. The crusher reduction is to minus 2½-inch with discharge to the mill conveyor belt, the latter being 250 feet long. As viewed from the scrubber catwalk the contrast between the muddy gravel approaching the scrubber on one side and the clean material retreating from it on the opposite side is particularly marked.

The aforementioned screw classifier can handle feed at the rate of about 200 tons per hour. Here settling, segregation, and washing action occur. The solids, with moisture content of minus 12 percent, are elevated by the screw, dewatered, and discharged onto a conveyor belt. The adjustable weir at the lower end aids control of the sizing. At an overflow rate of 1,000 gallons per minute the slimes contain 12 percent solids which will pass a 50-mesh screen. These slimes flow to a circular steel settling pond for fine-sand processing. The fine sand is recovered by a drag classifier, delivered to a 16-inch conveyor belt and dumped into a stand-storage bunker. The classifier overflow empties into an adjacent steel pond from which the water is reclaimed for reuse in the plant.

The mill conveyor belt from the scrubber leads to the top of the screening plant where a 4- by 14-foot three-deck Allis-Chalmers low-head, sizing screen with $1\frac{1}{4}$-inch, $\frac{7}{8}$-inch, and $\frac{1}{2}$-inch openings. Punched steel plate is used on top with wire cloth on the two lower decks. Rejects from the top deck pass by chute to a style B Allis-Chalmers double-deck screen with $2\frac{1}{2}$-inch and $1\frac{1}{2}$-inch openings. Material passing the lower deck of the low-head screen falls to a double-deck Allis-Chalmers low-head screen with openings of $\frac{5}{16}$-inch and $\frac{3}{16}$-inch. The sand is transferred to two adjacent counter-set 4- by 30-foot Wemco screw conveyors. The middle deck of the triple-deck screen rejects $1\frac{1}{4}$-inch gravel to the bunker, while the bottom deck rejects $\frac{3}{4}$-inch gravel to an adjoining bunker. Rejects from the top of the style B screen pass by chute to a Symons 3-foot secondary crusher. The secondary crusher-run product is returned to the screen feed. Rejects between $\frac{3}{16}$ and $\frac{5}{16}$ inches are chuted to a hopper feeding a closed circuit Symons 30-inch impact crusher, which makes a sand product and delivers it to the storage bunker.

There are eight 200-ton live-load concrete storage bunkers beneath the screening plant. Two bunkers receive sand (coarse and fine), and 1 bunker is allotted to each of the following products: $\frac{1}{4}$- to $\frac{1}{2}$-inch, $\frac{1}{2}$- to $\frac{3}{4}$-inch, $\frac{3}{4}$- to $1\frac{1}{4}$-inch, $1\frac{1}{4}$- to $1\frac{1}{2}$-inch, $1\frac{1}{2}$- to $2\frac{1}{2}$-inch; and a surge bunker. A 30-inch tunnel conveyor belt from beneath the bunkers permits loading any product or combination mix directly to railroad cars, or to the yard stock piles. A Brown railroad hoist with clamshell bucket loads cars from the yard stock piles.

The plant is a modern concrete and steel structure which was built in 1933 and is capable of producing about 400 tons of gravel per hour. Twenty-four men and a superintendent are employed the year round, and about 900 connected horsepower are required to run the equipment.

Castro Valley Rock Company (31) is located at 20450 John Street, Hayward, approximately in the NW$\frac{1}{4}$ sec. 9, T. 3 S., R. 2 W., M. D. Operator is B. F. Garfoals.

The face of the quarry is about 75 feet high and 150 feet long, being semi-circular in shape. Rock is loaded by a $\frac{5}{8}$-yard caterpillar mounted Byers shovel to trucks which haul the rock to jobs where it is used as road and fill material.

Concrete Materials Company (Livermore Rock Company) (32) is located in the S$\frac{1}{2}$ sec. 15, T. 3 S., R. 1 E., M. D. (projected), about $1\frac{3}{4}$ miles east of Pleasanton on the south side of the highway. The owner is W. C. Thompson, General Contractor, 1401 Illinois Street, San Francisco; G. L. Medlen is plant superintendent.

The company operates a power or drag scraper in Arroyo Valle on property acquired in August 1947.

The pit is dry, there is no overburden, and very few large boulders are encountered. The gravel removed during the dry season is usually replenished during the subsequent rainy season in years of normal rainfall. The digging installation consists of a head pulley, a tail tower, a side anchor block, the scraper, and about 900 feet of steel cable strung between them and the hoisting mechanism. The head pulley is attached to a vertical member of the screen-house frame at a point about 5 feet above ground level. On the opposite edge of the pit is a small portable pyramidal tower of steel tubing, about 4 feet high, to which the tail block is attached. Thus both the head and tail pulleys are at the same elevation, ground level. One end of the loading line is fastened to the front of a circular, partly covered, bottomless scraper, which draws the scraper across the pit and up a sloped bank on the delivery side, where the contents are dumped upon an 8- by 10-foot grizzly with 4-inch openings. The other end of the loading line is wound around a drum of a two-drum hoist, the latter being powered by a Buda diesel engine near the head end where the operator is afforded a clear view of the entire operation. The return cable is fastened to the back of the scraper.

The pit is semicircular in shape with a span of about 350 feet from head to tail pulley. Although the scraper is digging to a depth of about 30 feet, greater depths are attainable with this set-up. For each position of the head and tail pulleys, the scraper digs a trench about 4 feet wide from the ground surface downward throughout the entire length of its travel. By changing the position of the moveable tail tower and the anchor block the width of the trench is increased by degrees until it merges into and constitutes the boundary of the pit itself. Paths of excavation thus radiate from the head end of the pit. Auxiliary excavating equipment in an adjoining part of the creek-bed consists of a traxcavator that loads directly to dump trucks which haul a quarter of a mile to the aforementioned receiving grizzly.

Fines passing the grizzly are shunted around the 10- by 30-inch Pacific jaw crusher by a 1-inch stationary screen over its mouth. The crusher delivers minus 3-inch to a 200-foot bucket elevator that dumps into a bin at the top of the screenhouse. Wash water is introduced at the head of the vibrating screen where sand, and $\frac{3}{8}$-inch, $\frac{3}{4}$-inch, and $1\frac{1}{2}$-inch gravel are separated. Sand separation is effected by a set of two spiral classifiers about 4 by 10 feet in size. The products fall to nine 75-ton bunkers which permit direct truck loading or withdrawals to yard stock piles. For stock-pile withdrawals, the bunker chutes feed a pair of tandem-set horizontal conveyor belts, 100 and 150 feet long, respectively. The load of the latter belt may be delivered to the appropriate stock pile at any point along its line of travel by means of a car-wheel-mounted, manually operated tripper running on railroad rails. A tunnel conveyor belt with overhead feed gates passes beneath the stock piles and facilitates the loading of railroad cars.

Hayward Building Material Company. R. Close and E. L. Clement, owners, are operating on 5 acres leased from the California Nursery about 1 mile southwest of Niles on Alameda Creek. This is part of the extensive flood plain between the hills and San Francisco Bay. The actual creek bed is about 30 feet deep and 100 feet wide at this point. The gravel is low in clay and after crushing and sizing makes a satisfactory asphalt aggregate of 0-$\frac{7}{8}$-inch range. Maximum boulder size is about 10 inches.

The creek gravel is removed by a Buckeye crawler-mounted dragline excavator equipped with a 40-foot boom and three-quarter cubic yard McCaffrey bucket, and powered by a Chrysler eight-cylinder motor. The overburden, not more than 2 feet thick, is ''coarse-stacked,'' and the gravel is loaded to a fleet of three trucks which haul to a grizzly about a quarter of a mile away.

Crushing and sizing is done in a Cedar Rapids portable dry crushing plant powered by a 185-horsepower diesel engine. From the charging hopper gravel flows through a reciprocating feeder onto an inclined conveyor belt which elevates the material to a 4- by 15-foot double-deck vibrating screen with $1\frac{1}{2}$-inch and $\frac{7}{8}$-inch openings respectively. Oversize is rejected by the top screen to a 24 by 36-inch jaw crusher and by the bottom screen to a set of crushing rolls. The discharge from the jaw crusher is conveyed by a short horizontal belt to an 8-foot rotovator (circular bucket elevator), which empties onto a second short, horizontal, return conveyor belt to the top screen. Gravel from the rolls passes to a 50-foot inclined conveyor belt leading to the truck-loading bunker of 15-cubic-yard capacity. A total of eight men are employed on the combined operation and are assigned as follows: dragline, 2; crushing plant, 2; truckdrivers, 3; and truck dispatcher, 1. The output approaches 1000 tons per 8-hour day.

The cost of this material delivered to the asphalt plant is said to be about half the cost of "hauled-in" gravel. The portable asphalt plant using this product is set up on the floor of the old Casson ranch quarry on Highway 101 Alternate, about one mile east of the center of Hayward.

Heafey-Moore Company (Leona Quarry, Central Construction Company)[77] *(34)* is located in the SW$\frac{1}{4}$ sec. 2 and NW$\frac{1}{4}$ sec. 11, T. 2 S., R. 3 W., M. D. (projected), on the northeast side of Mountain Boulevard at Burkhatter Street, Oakland. Officers are John Heafey, president, M. J. Moore, vice-president, and J. A. McKenzie, quarry superintendent; offices are at 344 High Street, Oakland.

This property, comprising 110 acres, was purchased by the present owners in 1931. It is situated on a western slope of the San Leandro Hills which at this point rise from an elevation of 300 feet on Mountain Boulevard to more than 1100 feet at the ridge line. The plant yard has about half a mile frontage on Mountain Boulevard. The quarry rock is a well-fractured reddish-brown siliceous material resembling chert, locally known as "red rock," with seams of calcareous material filling many of the fractures. The soil overburden is less than a foot thick. It is distributed through the quarry-run rock when shot down, and is removed in the screening plant. There are three working faces. The first face is at the west end of the quarry and rises 150 feet above a bench, the latter being 60 feet above the yard level. This face stands nearly vertical. It is shot down with 45 percent dynamite and bag powder placed in 12 foot toe holes, and breaks readily into fragments easily handled by a $2\frac{1}{2}$-yard caterpillar-mounted Northwest diesel shovel. The second working face is at the 60-foot bench rising from the yard floor. This bench is advanced by a $1\frac{1}{2}$-yard caterpillar-mounted Northwest diesel shovel which makes two cuts of about 30 feet each. The third working face is in the eastern part of the quarry near the site of the glory hole of former operators. The quarry rock at this point is bluish-grey, dense, and highly silicified. After shooting, the fragments are loaded by a $\frac{1}{2}$-yard caterpillar-mounted Osgood diesel shovel, into two 5-yard Koehring dumptor (bottom dump) trucks which haul about a quarter of a mile to the crushing plant.

An electrically operated dry crushing and screening plant handles all the rock from the two upper quarry faces except that which is sold directly from the face as fill material. Trucks from the face dump to a roadside grizzly where the plus 18-inch is hand sledged. The minus 18-inch passes by chute to a 24- by 36-inch jaw crusher making a reduction to 6 inches. The crusher discharged to a 108-foot conveyor belt leading to a 4- by 24-foot trommel screen on the top floor of the plant. The trommel makes fines, $\frac{1}{4}$-inch, $\frac{3}{4}$-inch, and oversize. The oversize, consisting of 1- to

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[77] Laizure, C. McK, op. cit., p. 449, 1929.

6-inch rock, falls off the end of the screen onto the head of a Telsmith #10 gyratory crusher set in the floor. The Telsmith makes a further reduction to 2½ inches. This secondary discharge is carried by inclined chute to a short horizontal belt conveyor feeding a 3-foot Symons cone crusher; the latter will be replaced by a 4-foot Symons cone as soon as delivery can be obtained. The end products discharged from the Symons are raised by bucket elevator to a Symons vibrating screen where the following sizes are separated: 1½-inch, ¾-inch, ½-inch, and birdseye or minus ¼-inch. After sizing, these products are passed by chute to truck-loading bunkers. The crushing plant has a capacity of 400 tons per day based on an 8-hour shift. During the World War II period as much as 90,000 tons of rock per month were produced from this quarry on a 2-shift day. Much of the latter production was fill material, however, and delivery loading was possible at the working face. The connected horsepower for the crushing plant is as follows: jaw crusher, 75; gyratory, 75; cone crusher, 60; Symons screen, 10; elevator, 7½; and belt, 7½; totaling 235 horsepower.

The rock produced from the lower bench adjoining the yard floor is run directly through a Universal Engineering portable crushing plant and field storage bunker, which can be advanced as quarrying progresses. The mobile plant consists of a 24- by 30-inch jaw crusher and a 25-foot conveyor belt delivering crusher-run material to the storage bunker. Either a 1½-inch or 2½-inch crusher-run product can be made, depending on the set of the crusher, which can be changed to meet the demand.

A slurry base plant with a 400 ton per day capacity is also on the property. Other equipment used includes two 7-ton Mack trucks for yard work, a ¾-yard P and H shovel, and two ¾-yard Northwest shovels for loading trucks from yard stock piles. Twenty-four men and a superintendent are employed in the combined quarry and plant operations.

Inland Aggregates Company, Inc. (35) is located approximately in the W½ sec. 20, T. 4 S., R. 1 W., M.D., about 2 miles west of Niles on property of the California Nursery Company. Operator is Mr. Saldini of Niles.

The overburden at this property on the north side of Alameda Creek, where present, ranges from a thin cover to 3 feet. Practically no boulders are present in the gravel. Mining is done with a ¾-yard P and H caterpillar-mounted shovel and the gravel is trucked a quarter of a mile and dumped on an 8- by 12-foot grizzly of concrete and steel construction. The gravel drops through 8-inch openings to a loader and passes to a 24-inch 50-foot inclined belt conveyor discharging onto a 4- by 6-foot grizzly of steel rails with 2-inch openings. The oversize is fed to a 10- by 20-inch Pacific jaw crusher. The undersize and crusher-run rock falls to a 24-inch 50-foot inclined belt conveyor discharging through a 1-inch screen which passes oversize to a 3-foot Symons cone crusher. This crusher undersize is conveyed 50 feet to three sets of vertically staggered vibrating screens where plus ¾-inch, plus ⅜-inch, and plus sand products are separated and stock piled by radiating belts. The undersize from the screens passes to a 5- by 15-foot Bodenson dual-rake classifier from which the sand is discharged to a stock pile by a 75-foot inclined belt conveyor. The stock piles are built up from the top of a 150-foot subterranean longitudinal concrete tunnel, through which any product can be drawn to a 225-foot belt conveyor feeding a truck loading bin. A set of 13 levers control the flow of stock pile products through the underlying tunnel gates. The plant is electrically operated.

Henry J. Kaiser Company (36) plant is located in sec. 21, T. 4 S., R. 1 W., M. D. (projected), Niles. Officers are R. S. Barneyback, general manager, 1924 Broadway, Oakland, and B. F. Carter, plant superintendent, Niles.

This new sand and gravel plant started operating June 1, 1949, on a 42-acre tract between the south bank of Alameda Creek and the Alameda County corporations yard. Overburden ranges from about 8 feet on the west edge to about 15 feet on the east edge of the tract. Most of the gravel is minus 6-inch in size. The overburden is removed and the gravel is mined by a caterpillar D-8 diesel engine and a 20-ton caterpillar carryall in tandem. At the east edge of the pit area the gravel is bottom-dumped on a 15- by 15-foot grizzly with 6-inch openings, which overlies the receiving hopper. A 2-inch scalping screen shunts the oversize through an 18- by 36-inch alloy-steel jaw crusher. The undersize and crusher-run gravel pass to a 250-foot inclined belt and are conveyed to the transfer point. An 80-foot inclined cross-belt conveys the gravel to a primary double-deck Diamond vibrating screen. The screen oversize, plus $1\frac{1}{4}$-inch gravel, is run through a 4-foot Symons cone crusher. The crusher discharge is reconveyed to the transfer point and returned to the primary screen for rescreening. The plus $\frac{1}{4}$-inch minus $1\frac{1}{4}$-inch gravel is washed, transferred to an inclined belt, and conveyed to a secondary screen. The minus $\frac{1}{4}$-inch material is the source of either dry or wet sand. The dry sand is conveyed directly to a stock pile and used in asphaltic concrete. Wet-washed sand is prepared in a Dorr duplex dual-flight classifier. At the secondary screen, a triple-deck Diamond, the following products are washed, separated, and dropped to stock piles: $\frac{3}{4}$-inch, $\frac{1}{2}$-inch, $\frac{5}{16}$-inch, and $\frac{1}{4}$-inch. Two tunnel conveyors underlie the stock piles. One conveyor leads to a 100-ton elevated conical-bottom bunker for truck loading. The second conveyor moves in the opposite direction and supplies raw material to an asphalt plant.

The plant operates 5 days per week on one 8-hour shift, employing 12 men. It is electrically operated by 600 connected horsepower, and has a rated production capacity of 125 tons per hour.

Henry J. Kaiser Company (Kaiser Paving Company)[78] *(37)* is located in sec. 15, T. 3 S., R. 1 E. (projected), four-tenths of a mile east of Radum Station on the Pleasanton-Livermore highway. Officers are R. S. Barneyback, general manager, of 1924 Broadway, Oakland; and B. F. Carter, superintendent, and A. Abrott, plant engineer, of Radum.

The plant was built in 1932 to produce rock aggregates from sand and gravel mined on the flood plain of Arroyo Valle in the Livermore Valley. It replaced a smaller plant formerly operated in Livermore. At the former location the gravels seldom exceeded 15 feet in depth, but at the present pit they are mined to a depth of 70 feet.

A layer of overburden, which in many places reaches a depth of 20 feet, overlies the gravels in this vicinity. This overburden is removed by two caterpillar D-7 scrapers and 2 LP Le Torneau carryalls. The gravel pit is divided into two parts separated by a narrow earth bank. One part is a large rectangular opening representing the worked-out area, which is now used as a fines settling pond. The other part, a small narrow rectangular opening about $\frac{1}{10}$ by $\frac{1}{4}$ of a mile, is the present working area.

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[78] Laizure, C. McK, op. cit., p. 450, 1929.

A completely revolving electrically operated crawler-mounted Monighan dragline with a 140-foot boom works on a bench 10 feet above the water level. This dragline is equipped with a 10-cubic yard bucket and digs 30 feet below the water. The dragline dumps its load to a floating hopper in the corner of the working pond. The floating hopper discharges its contents to a pendulum conveyor belt about 140 feet long, which terminates at the ''pit lateral'' conveyor belt. The latter is about 3 feet wide and a quarter of a mile in length.

Thirty feet above the level of the Monighan a second dragline works on a higher bank. This dragline is a Bucyrus-Erie with an 80-foot boom and a 5-cubic yard bucket. It feeds a mobile field hopper at the receiving end of the ''pit lateral' conveyor belt.

The ''pit lateral'' conveyor thus receives gravel at two points. At the delivery end it terminates in a mobile field hopper mounted on railroad rails set over the primary conveyor belt leading out of the pit.

A primary washing and screening is made at this transfer point where about 75 percent of the clay is removed. Two Tyler double-deck screens and two Wemco dewatering screws are used in the process; the fluid is returned to the settling pond. The semicleaned gravel is then transported about a mile to the crude stock pile at the main washing plant by a series of five belt conveyors. There is a dog-leg bend in the conveyor system about midway to the washing plant.

Gravel from the crude stock pile is drawn through four gates to the underlying conveyor tunnel. A 6-inch scalping screen separates the oversize, passing it to an 18- by 30-inch Allis-Chalmers jaw crusher, whence it is returned to ''pit run.'' The screened material is conveyed to the top of the plant by a series of short belts. Here the plus 2⅞-inch material is separated and run through a 4-foot Symons cone crusher and returned for rescreening. A group of 22 vibrating screens, 6 drag-sand classifiers, 5 rake classifiers, 2 Dorr bowl classifiers, and 1 Dorr scoop classifier, constitute the plant equipment at this point. They are combined in a series of operations to deliver the following products: 1½ to 2½ inch, 1 to 1½ inch, ¾ to 1¼ inch, ⅝ to ⅞ inch, ⅜ to ⅝ inch, ⅛ to ¼ inch (roofing gravel), 6-mesh to ⅜ inch (pea gravel), and sand. The first six of these products are run to silos, each having a capacity of about 1000 tons.

These stocks may be drawn to a surge bin where they are washed, rescreened, and blended to meet definite specifications. Railroad cars are loaded directly from the storage bins by belt conveyors. The pea gravel (minus ⅜-inch) is stock piled and the excess material may be drawn through an underlying 75-foot tunnel conveyor to an 8- by 12-foot Marcy rod mill where it is reduced to sand. After reduction it is washed, screened on a 4- by 10-foot Robbins vibrating screen, classified in a 15-foot Dorr bowl classifier, and conveyed to a 250-ton storage bunker. The sand is used in asphalt and concrete mixes. The property contains an asphalt plant and a ready-mix concrete plant which can deliver either to trucks or railroad cars. Sand production from the Marcy mill runs about 50 tons per hour, and rod consumption is about 1 pound per ton of sand.

A blacksmith shop, a machine shop equipped with lathes and drill presses, and a small laboratory adjoin the screening plant. The yard equipment includes two Brown-Hoist railroad cranes with clamshell buckets for train loading from stock pile, a ⅝-cubic yard Northwest crane with clamshell bucket, a ⅝-cubic yard Lorrain shovel for loading fill material, a ½-cubic yard Bucyrus-Erie shovel, and five diesel electric locomotives (one 40 ton, one 35 ton, two 25 ton, and one 10 ton). The plant is served by the Western Pacific and the Southern Pacific railroads.

The plant operates from 7 a.m. to 3 p.m. on a 5-day week. In order to reduce the peak power load, the pit is operated on a 3 to 11 p.m. shift. About 120 men are employed all year round and production is rated at 1000 tons per hour.

Niles quarry (Russell quarry) (39) is located approximately in the NE¼ sec. 17, T. 4 S., R. 1 W., M.D., about three-quarters of a mile west of Niles. Operators are Sawyer and Silva, 4061 Highland Boulevard, Hayward.

The present operators have been producing at this plant since spring of 1946. The face is about 175 feet high and 300 feet wide, part of which consists of metamorphosed conglomerate and chert. The material is known locally as ''red rock''. The rock is loaded by a ½-yard P and H shovel which hauls about 100 yards to a 4- by 20-foot grizzly of steel rails with 12-inch openings set over a chute leading to a 24- by 36-inch Llewellyn jaw crusher. The crusher is run by a 40-horsepower motor and crushes to minus 6-inch. The crusher-run rock is discharged to an inclined conveyor belt about 100 feet long terminating in a 2- by 6-foot screen with 1½-inch openings making fine, medium, and coarse rock which is discharged into a 150-ton bunker set over a truck-loading tunnel. Five men are employed for 8 hours a day in a 6-day week. Plant capacity is about 500 tons per day.

Pacific Coast Aggregates, Inc. officers are A. K. Humphries, president; E. J. Goodpastor, general manager; R. K. Humphries, assistant general manager; and George Hampton, chief engineer. The offices are at 400 Alabama Street, San Francisco.

This company was incorporated in California on November 30, 1928, as Pacific Aggregates, Inc., and acquired the property of Rhodes-Jamieson Company; Associated Gravel Company and distributing plants operated by the Acme Gravel Company; Pratt Rock and Gravel Company and Pratt Building Materials Company with subsidiaries; Bay Development Company with subsidiaries; Santa Clara Gravel Company; G. and M. Gravel Company; T. I. Butler Company, Inc.; California Building Material Company; Piedra Rock Company; Golden Gate-Atlas Material Company (except ready-mix concrete business); and California Rock Company. The present name was adopted on April 15, 1929. In 1946 the company purchased the Sacramento Rock and Sand Company. The Grant-Pacific Rock Company is a subsidiary.

The company now owns or operates fifteen production plants, eight distribution plants, and six wholesale warehouses with delivery equipment. About 2500 acres of sand and gravel deposits are owned or under lease. The company was reorganized on December 17, 1934. The present capital stock consists of 30,000 shares of 4½ percent cumulative convertible preferred stock, par $100; and an authorized 1,500,000 shares of $5 par common stock, of which 736,929 shares are outstanding. An average dividend of 23¢ per common share has been paid since 1941. The stock is listed on the San Francisco stock exchange. The price range in 1948 was $4¼ to $6½.

Pacific Coast Aggregates Centerville plant, No. 106 *(40)*, is located approximately in sec. 19, T. 4 S., R. 1 W., M.D. (projected), about half a mile north of State Highway 17 and Thornton Road. Q. A. Collinson, Centerville, is plant superintendent.

The Centerville plant commenced operating in June 1948, on part of a 300-acre holding on the south side of Alameda Creek. A 3-foot surface layer of overburden is removed by Wooldridge carryall. The gravel is mined by a Link-Belt dragline equipped with a 55-foot boom and a 2-yard Esco bucket, powered by a caterpillar D-13000 diesel engine. The dragline makes a 25-foot cut and loads gravel to a fleet of three 25-ton Euclid dump trucks. The truck haul is about half a mile to a 16- by 16-foot grizzly of steel rails with 7-inch spacing. Very few oversize boulders are present.

The pit-run gravel is carried 107 feet by an inclined belt conveyor to a transfer point, then 60 feet by an inclined cross belt to a scalping screen making ½-inch or 1½-inch products. The screen oversize rejects pass to a 10- by 36-inch Diamond jaw crusher, then to a 4- by 10-foot deck and a half Diamond screen. Various desired gravel sizes may be separated at this point depending on the screen selected. Oversize rejects from this screen are passed to a 22- by 40-inch Diamond roll crusher and returned to raw feed.

The minus 1½-inch gravel from the scalping screen falls to a conveyor belt and is carried 100 feet to a three-deck, 4- by 12-foot Diamond screen. Here it is spray washed, sized, and discharged to radiating stacker belts leading to the stock piles. The minus ¼-inch (sand) is flumed to a 48-inch Wemco, double-flight dewatering screw, whose production capacity is 130 tons of sand per hour. Sand passes from the screw to a stacker belt and is conveyed to the sand stock pile. Silt and water from the screw flow to a sump where they are picked up by a 6-inch Kimble-Crow centrifugal sand pump and moved 1,800 feet laterally to the waste water pond. Water from this pond is reclaimed for adjacent agricultural operations after the sediment has settled. Washed and sized gravel from the stock piles is transferred to six adjoining 100-ton self-cleaning steel bins by a Northwest dragline with a 25-foot boom and a 1½-yard clamshell bucket. The 25-ton delivery trucks are loaded from these bins, weighed, and tagged in a 4-minute period.

Water for washing operations is obtained from a well 527 feet deep. It is cased to the 300-foot point and is cemented at 120 feet. A 150-horsepower vertical turbine driven pump produces water at the rate of 1,800 gallons per minute.

The plant runs two 10-hour shifts on a 5-day week. It is electrically operated, employs 36 men, and has a production capacity of 250 tons of washed gravel per hour.

Pacific Coast Aggregates Eliot plants Nos. 103, 118, and 104 [79] *(41)* are located in sec. 14, T. 3 S., R. 1 E., M.D. (projected), on Arroyo Valle, south of Eliot station, about 2½ miles east of Pleasanton on the Livermore highway. D. A. Gildersleeve is the Eliot plant superintendent.

The holdings of the company extend along the stream bed of Arroyo Valle for a distance of about 3 miles. After removing about 3 feet of overburden, the gravels are mined to a depth of about 70 feet, although well drill holes have established their presence at depths of more than

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[79] Laizure, C. McK, op. cit., pp. 451-455, 1929.

300 feet. The deep gravels, however, contain a proportionately greater percentage of large boulders and handling them would increase production costs on present-day products. The removal of interstratified clay beds would offer an additional problem and also increase production costs. Therefore, until such time as depletion becomes a factor, it appears unlikely that excavation will exceed the present depths. The company has operated three pits and three plants on this property. Plant No. 103, the older plant, was operated by this company from 1929 to January 1949. Here mining was done with a completely revolving railroad-mounted Bucyrus-Erie dragline. This dragline was "set up" on the surface of the ground and cut the walls of the pit to a depth of 50 feet where a bench was formed. A second dragline was "set up" on the bench and cut the remaining distance of 25 feet to the water level. The latter was a caterpillar-mounted Link-Belt dragline. The Bucyrus dragline loaded to side-dump railroad cars powered by two General Electric diesel-electric locomotives. The Link-Belt dragline loaded to trucks.

The railroad cars dumped to a track hopper set with a grizzly having 10-inch openings through which the gravel dropped to a tunnel conveyor belt leading to the crushing house. There, the gravel was received by a 6- by 30-foot trommel which washed and separated ½-inch, 1½-inch, and 3-inch sizes. The fines were screened out and handled by two rake classifiers and two Link-Belt classifiers which discharged to the sand stock piles. The oversize was passed to an Allis-Chalmers 2N gyratory crusher, and the crusher-run material was transported by belt to the screenhouse. Here the crusher-run material passed through another 5- by 25-foot trommel and two sets of three- and four-deck vibrating screens, where the final separations were made. Sand was handled by two revolving classifiers. Plant 103 is worn out and is now idle.

Plant No. 118 is located about half a mile east of Plant No. 103. It is of frame construction and was built to relieve the older plant of part of the peak production loads developed during the years of World War II. The crude gravel for Plant No. 118 is mined from the flood plain of Arroyo Valle about 2 miles east of the plant. A caterpillar-mounted 2-cubic yard Northwest dragline digs to a depth of 15 feet below the surface, after removing about 3 feet of overburden by "casting over." During years of normal rainfall, about 18 inches in this area, the creek gravels at this point are completely replenished. There has been little replenishment, however, during the winters of 1946 and 1947. The dragline dumps to an elevated mobile field hopper of about 35-cubic yard capacity. The hopper is discharged manually to two 20-ton Euclid bottom-dump trucks which shuttle to the plant.

The Euclid trucks dump over a grizzly with 10-inch openings set at ground level above a conveyor tunnel. The gravel is transported to a 4- by 24-foot trommel of punched steel plate, surrounded by a 6-foot jacket section of ⅜-inch mesh screen. The trommel makes separation up to 3 inches in size and the plus 3-inch material passes out the lower end to an 18- by 24-inch Llewellyn jaw crusher. The crusher-run material is transported by belt to a second trommel, with ½-inch and 1½-inch openings, and two Symons 4- by 12-foot vibrating screens, thence to storage bunkers. A 3-foot Symons cone performs the secondary crushing.

Pea gravel, minus ⅜-inch in size, has long been the bane of the large gravel plants because the product is nearly always produced in quantities far in excess of demand. An economical method of reducing pea gravel to sand has recently been worked out in this plant, largely as a result of the development of an improved type rod mill.

The following discussion of the method is quoted from a recent article by Gildersleeve.[80]

> "The rod mill, a 5x10-foot Marcy, is fed into both ends and discharges through peripheral ports in the center of the shell. This type of mill will produce a better grade of sand than the old style, full length, mill commonly used in ore grinding where extreme fineness is required, because most of the grinding is done the first 4 or 5 ft. after the material enters the mill and from there on needless pulverizing takes place. In the new type mill greater capacity is possible and more efficient operation results from what is virtually two mills in one.
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> "It is fed by two Reeves variable speed screw feeders mounted on small car wheels and rails, that can be rolled back in the clear for inspection of the mill or removal and replacement of rods. A water jacket through the feeders allows water to be injected along with the feed. These screw feeders receive their supply by gravity from overhead bins kept filled to the proper level by a conveyor belt which carries the material up from a hopper under which a controllable feed gate is located. It is possible to maintain a positive uniform feed with these Reeves feeders.
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> "The mill is driven by a 100 hp. electric motor through V-belt pulleys, and it turns at the rate of 26 r.p.m. The one-inch thick steel shell is lined with alloy-steel approximately 3 in. thick, securely bolted to the shell. Manganese steel is generally used for lining these mills, this being one exception. The grinding rods are 10 ft. long. At the outset 11 tons of rods were placed in the mill, consisting of three sizes: 2-in., 2½-in. and 3-in.
>
> "The product of the mill is lifted by bucket elevator high enough to be flumed to a 4 by 12-ft. Symons vibrating screen where it blends with the regular mill run sand and passes on to a drag type classifier and thence by conveyor belt to stockpile from which it is loaded into cars for shipment.
>
> "Only enough water is used (approximately 20 gal. per minute) at full feed, to keep the pulp in a fluid state. Experimenting with different amounts of water brought two very definite conclusions: (1) too much water has a tendency to sluice the material through the mill thereby reducing its grinding efficiency; (2) not enough water causes pulp to build up between the rods practically stopping the grinding effect altogether.
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> "Following are some screen analyses showing the fineness of sand produced with different feed loads. These samples were taken directly from the mill before being screened or classified.

	Feed Load		
Passing screen	51 TPH	30 TPH	20 TPH
½ Inch	84 percent		
4 Mesh	78	100 percent	100 percent
8 Mesh	41	90	91
16 Mesh	23	65	76
30 Mesh	14	41	62
50 Mesh	8	25	24
100 Mesh	3	11	9
200 Mesh	1	3	3

> "From these screen tests it can be seen that if a very fine product is required for blending with coarse sand, it can be made by simply reducing the input to the mill. Also it is notable that at peak load of 51 t.p.h. 16 per cent is rejected over a ½ in. screen which gives a net production of approximately 43 t.p.h.
>
> "This mill has clearly demonstrated that commercial sand can be ground economically from gravel. The first cost of an installation of this sort may be high but low operating and maintenance costs will make its use profitable to the producer where sand is needed to balance his plant output."

Pacific Coast Aggregates Plant No. 104, a new $2,000,000 composite plant (sand and gravel—crushed rock) was placed in production by the

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[80] Gildersleeve, D. A., Rod mill grinding experience: Rock Products, p. 105, October 1947.

Pacific Coast Aggregates Company in January 1949. This plant was designed by the Conveyor Company of Los Angeles, and includes the most modern features of concrete and steel design. Concrete for the conveyor tunnels was first poured in 1947. It is located about a mile west of Plant No. 103 and a quarter of a mile north of the Arroyo Valle creek bed.

The plant consists of four units: a scrubbing unit, which feeds on crude pit-gravel and delivers a series of washed products to the stock piles; a crushed rock unit, which feeds on oversize gravel from the scrubbing unit and delivers a series of crushed products to the stock piles; a transfer station; and a screening-blending unit, which draws on the stock piles and delivers specification products for shipment and bulk storage.

Crude gravel is mined from a bowl-shaped pit about 400 feet in diameter at the surface. Three 20-ton capacity Wooldridge terracobras, powered by 150-horsepower Cummings diesel engines, are used in the excavation work.

When digging its load the terracobra requires additional power. This extra ''push'' is supplied at the rear by a caterpillar D-8 diesel bulldozer. The terracobras begin loading at the rim of the bowl, proceed down the side toward the bottom, and discharge by bottom-dump to a grizzly located in the center, about 50 feet vertically below the rim of the bowl. The grizzly is about 12 by 20 feet with 10-inch openings, and consists of 90-pound inverted steel rails set in concrete.

Gravel falls through the grizzly to a hopper where a reciprocating feeder moves it to the pit conveyor belt leading to the scrubbing plant. The belt is 42 inches wide, 1,080 feet long, and moves at the rate of 360 feet per minute. At the top of the scrubbing unit the gravel is discharged to a hopper where water is introduced and the entire mass passes by chute to a cylindrical blade mill or scrubber. The latter is 8 feet in diameter and 30 feet in length. It revolves about its longitudinal axis, which is set in a horizontal plane. Additional wash water is introduced at this point. The interior of the cylinder is lined with rows of deflectors or blades which assist in separating the sand and gravel, prevent the latter from riding around the circumference of the cylinder, and propel the products toward the exit at the opposite end.

Mixed sand and gravel from the scrubber passes to an Allis-Chalmers triple-deck vibrating screen where the following products are separated: oversize, plus 4-inch gravel, off the end of the top deck; minus 4-inch plus 2½-inch gravel, off the end of the middle deck; minus 2½-inch plus 1½-inch gravel, off the end of the bottom deck; and undersize gravel, minus 1½-inch in size. The minus 4-inch passes by chute to an Allis-Chalmers 6N gyratory crusher. The crusher product is conveyed to the appropriate surge pile. The undersize passes to a set of two Allis-Chalmers ripple-flow double-deck screens where three additional products are separated, namely: minus 1½-inch plus ½-inch, minus ½-inch plus ¼-inch, and minus ¼-inch or sand. The sand and wash water pass through both decks and are flumed to a pair of settling tanks. The water flows to the outdoor settling pond and the sand passes to a 6- by 10-foot sand wheel where the remainder of the water is removed. All final screen products are conveyed to the appropriate stock pile or surge pile by a group of two 36-inch and two 24-inch conveyor belts, 700 feet long, radiating from the bottom of the scrubbing plant.

The surge piles represent intermediate stocks of washed gravel which may be sold without further processing, or which may be used as a source material for blended products. These cone-shaped piles are built up from the top of concrete conveyor tunnels erected on the surface of the ground. Emerging from the tunnels are three conveyor belts which converge at the transfer station, bringing in surge materials as required for sale or blending. Here, the surge products are transferred from three converging belts to two parallel belts and continue on their journey to the blending and screening unit some 250 feet distant.

The material received at the top of the blending unit is rewashed and rescreened by five Allis Chalmers low-head double-deck screens. These screen products pass by chute to another group of five similar type screens and a sand wheel for close grading and a subdivision of sand products. At this point four sand products and eight gravel products are made, as follows: (1) sand—minus 16-mesh, plus 16-mesh minus 8-mesh, plus 8-mesh minus 4-mesh, and plus 4-mesh minus ¼-inch; (2) gravel—plus ¼-inch minus ⅜-inch, plus ⅜-inch minus ½-inch, plus ½-inch minus ⅝-inch, plus ⅝-inch minus ⅞-inch, plus ⅞-inch minus 1-inch, plus 1-inch minus 1¼-inch, plus 1¼-inch minus 1½-inch, and plus 1½-inch minus 2½-inch. Other products may be made as demand arises by changing the screen sizes at suitable points. These final products pass by chute to underlying concrete storage bunkers. Wash water from the blending unit is flumed to a Wemco dewatering screw at ground level. Here, an additional sand separation is made and the water is returned to the pond for clarification and reuse.

The rectangular storage unit consists of twenty 250-ton bunkers in two rows of ten bunkers each. This unit was designed primarily for railroad-car loading and spur tracks of the Southern Pacific Railroad flank the unit on either side. The bunkers can be discharged by bottom dump gates to an underlying conveyor belt 664 feet long running the length of the building. The discharge gates are operated by a series of levers from a central control point. In this way products may be blended directly on the belt itself. The conveyor is inclined upward at the end of the bunkers, elevating and discharging its load to a cross conveyor for railroad car loading. Each car receives a load of approximately 60 tons. The crushed rock unit of the plant will be placed in operation as soon as it is completed.

The plant is electrically operated throughout and a connected load of 3,500 horsepower is required for its operation. Electricity at 60,000 volts is supplied by the Pacific Gas & Electric Company to the local transformer station. Here it is stepped down to 4,000 volts, thence to several transformer stations where it is stepped down to 440 volts for use in the plant. Water is required at the rate of 2,500 gallons per minute. This is supplied in part by two wells pumping at a combined rate of 1,500 gallons per minute. The water horizon is located at a depth of approximately 70 feet below the surface. The balance of the water supply is obtained by reclaiming the wash water in a series of settling ponds.

A total of 45 men are employed at the plant on a stable year-round basis. Three crews work on a 40-hour week. Two shifts of 8 hours each operate the scrubber unit of the plant from 6 a.m. until 10 p.m. The finishing mill or screening plant operates one shift only.

Pacific Coast Aggregates Niles plant, No. 105 [81] *(42)*, is located in sec. 21, T. 4 S., R. 1 W. (projected), on Alameda Creek south of Niles. Q. A. Collinson is plant superintendent.

This is one of the first plants established to produce concrete aggregates in the San Francisco Bay area. It was erected in 1910 by William Ford near the apex of the large alluvial cone built by Alameda Creek from the watershed of the adjoining foothills southwest of the Livermore Valley. The thickness of this alluvium has not been determined, as no well has reached bed rock. It is reported that a water company well was drilled to a depth of 1,000 feet in the alluvial material. The present pit, about a mile southwest of the plant, is 150 feet deep and about 600 feet in diameter. Ground water is encountered at a depth of 100 feet and thus establishes the lower level of mining. The sand and gravel are removed by a Marion electric dragline using a 60-foot boom and 90 feet of line. Three horizontal cuts are necessary to attain the required depth. The boom is equipped with a $2\frac{1}{4}$-cubic yard Esco bucket, and dumps the excavated material into an elevated 40-ton field hopper. The hopper is set for bottom dumping to a gondola-type railroad car. Hauling is done by an 18-ton Plymouth locomotive powered by a six-cylinder Climax gas engine. Two of these units are in service and shuttle between pit and plant on a standard-gauge single track with one turnout.

Arriving at the plant yard the cars discharge their contents to a concrete pit 40 feet long installed beneath the track. From the pit sand and gravel flow by gravity through four manually controlled feed gates to a conveyor belt which transports the material to the top of the screen-house where the actual separation of products begins. All the plus 4-inch gravel is removed by a grizzly to a Gates crusher and a Symons 3-foot cone crusher, and is then conveyed to the crushed-rock section of the plant containing a 4- by 10-foot Symons double-deck vibrating screen. The minus $\frac{1}{8}$-inch and the plus $\frac{3}{4}$-inch is returned to raw feed.

The minus 4-inch gravel from the pit is conveyed to the gravel section of the plant. Two Link-Belt scrubbers remove the minus $\frac{3}{16}$-inch material which passes down a sand chute to a Bodinson dewatering classifier. This classifier ejects the sand to four sand boxes which dump to the ''concrete sand'' bunker. The sand box overflow (containing excess fines) passes to a Link-Belt dewatering drag classifier and is then delivered to the ''asphalt sand'' bunker. The waste water from these operations is returned to a settling pond. The plus $\frac{3}{16}$-inch gravel passes to two conical screens, which reject the $2\frac{1}{2}$- to 4-inch material, and from then to a Symons crusher bunker. The remaining gravel, $\frac{3}{16}$- to $2\frac{1}{2}$-inch, passes over six double-deck company designed vibrating screens, where the following separations are made: $\frac{3}{16}$ to $\frac{5}{16}$ inch, $\frac{5}{16}$ to $\frac{7}{16}$ inch (pea gravel), $\frac{7}{16}$ to $\frac{7}{8}$ inch, $\frac{7}{8}$ to $1\frac{1}{4}$ inch, $1\frac{1}{4}$ to $1\frac{5}{8}$ inch, and $1\frac{5}{8}$ to $2\frac{1}{2}$ inch gravel.

A Whitcomb gasoline locomotive and a diesel Brown-Hoist with a $1\frac{1}{2}$-cubic-yard clamshell bucket are used for yard loading of railroad cars. The plant is served by spur tracks to the main lines of both the Southern Pacific and the Western Pacific railroads.

This plant employs 20 men, operates on an 8-hour shift for 5 days a week, and has a production capacity of 150 tons per hour. Plans are under way for the removal of these operations to Centerville, about 2 miles southwest of Niles, where a completely modern crushing and screening plant was constructed in 1948.

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[81] Laizure, C. McK, op. cit., pp. 451-455, 1929.

Picard gravel pit (43) is located in the SW¼ sec. 17, T. 3 S., R. 1 E., M. D. (projected), at the north edge of Pleasanton about half a mile west of the highway. A. B. Picard, 300 St. Mary's Ave., Pleasanton, is the owner; Mr. Dietz is the lessee.

Gravel is removed from a strip along the present bed of Arroyo Valle near its lower end. There is no overburden and the pit is self-sustaining, that is, it is replenished during seasons of normal rainfall. At the point of operations the pit is about 150 feet wide and 30 feet deep and the percentage of 10 to 12 inch boulders is very low.

Three methods of excavation are employed here, all on a small scale, namely: drag scraper, dragline excavator, and slack-line cableway excavator. Pit-run gravel is delivered directly to trucks by a ½-cubic yard drag scraper powered by a Le Roi portable engine. The scraper contents are deposited on a grizzly with 3-inch openings and fall through to the bed of the delivery truck. Pit-run gravel can also be delivered directly to trucks by a P & H No. 20 excavator with a 25-foot boom and dragline bucket. The excavator loads to a small field hopper. The discharge from the hopper passes over a 3- by 6-foot stationary screen with 1-inch openings, and the plus 1-inch gravel is delivered to a truck off the end of the screen.

A large portion of the gravel excavated is used by the lessee as an aggregate in ready-mix concrete. A slackline cableway excavator is used to build up the aggregate stock pile. This equipment consists of a 70-foot wooden head-pole on the south bank of the creek and an anchored tail tower on the north bank. The cableway carries a 2-cubic yard bucket and stretches across the creek bed, which is about 50 feet deep. In operation, the bucket descends the cableway by gravity. The cableway is slacked, dropping the bucket into the pit for a load. The bucket is drawn forward and filled, the cableway is tightened, power is applied, and the bucket ascends the taut cableway to the point of discharge where it is automatically tripped, dumping its contents on the stock pile. Power for these operations is supplied by a Chevrolet six-cylinder engine running on butane, and is transmitted to the bucket through a two-drum hoist mounted near the head end. The inhaul cable may be operated at two speeds, a low (power) speed for digging, and a high speed for hauling. When the limit of bucket excavation has been reached the tail tower may be moved laterally, or a bulldozer feeds the bucket gravel from the area adjacent to the cut.

Gravel dumped from the bucket falls on the aggregate stock pile which builds up from the top of a concrete truck-loading tunnel set flush with the ground level. The tunnel is approximately 10 by 12 feet and 125 feet in length with overhead loading gates. Bulk cement is lifted to a cylindrical distribution bin by a 30-foot vertical enclosed Bacon elevator. Three men are occupied on this property.

San Leandro Rock Company (44) is located approximately in the SE¼ sec., 30, T. 2 S., R. 2 W., M. D. (projected), on Chabot Avenue about 2 miles north of Hollywood Boulevard. Owner is U. B. Lee, 1159 Estudillo Avenue, San Leandro, who has operated the quarry and plant since 1934; quarry superintendent is J. Coons.

This property consists of about 20 acres near the Lake Chabot Dam. Present quarry face is about 350 feet high and 500 feet long. The face is shot down about once in 6 weeks with a 40 percent Trojan explosive in toe-holes which number about 30. About 3 tons of explosive are used. Bulldozing is necessary on many of the large boulders which come down. The rock is loaded with a 1¼-yard Lima caterpillar mounted shovel. A ¾-yard shovel is also in use. The rock is trucked to a grizzly of steel rails, at the edge of the quarry floor, which feeds the jaw crusher. From the crusher rock passes by a 50-foot incline conveyor belt to a 4- by 15-foot trommel screen with plate openings 1 to 1½ inches in diameter. A parallel conveyor and trommel makes ¾-inch, 1½-inch, and 3-inch fragments. Oversize from these screens passes to the recrushing plant, consisting of a 36-inch Telesmith gyrosphere. From the secondary crusher a bucket elevator lifts the material 100 feet to a third trommel screen making 1-inch and 1½-inch separations which are discharged to a three-deck Seco vibrating screen making the following products: 0 to ¾, ⅜ to ¾, ¾ to 1½, and 1½ plus. The products are discharged to six steel bunkers of about 100 tons capacity each. The bunkers have pyramidal bottoms and easily operated hand loading gates which load directly to trucks. Fifteen men are employed in operating the quarry and plant. Production capacity is 5,000 cubic yards a month.

Silva Brothers gravel (45) property is located in the NW¼ sec. 22, T. 4 S., R. 1 W., M. D. (projected), on the north side of U. S. Highway 101 Alternate, and the east side of Alameda Creek, Niles. Owners are Herman and Lauren Silva, 1662 Bridge Street, Hayward, who have been operating the property for about 14 years.

The property comprises about 40 acres located on the alluvial cone built up by Alameda Creek as it discharges onto the plain at the mouth of Niles (Alameda) Canyon. The maximum depth of gravel exposed is 50 feet.

Typical section of gravel at Silva Brothers pit, Niles.

Log	Estimated thickness
Topsoil	2 feet
Gravel (0 to 6 inches in size)	2 feet
Sand (fingers of gravel 0-3 inches in size)	3 feet
Gravel (0-2 inches in size)	1 foot
Compacted sand	2 feet
Gravel (1½-6 inches in size)	11 feet

The gravel is loaded by diesel shovel and trucked about a quarter of a mile to a bin set with a steel-rail grizzly having 8-inch openings. From the receiving bin the gravel is drawn into a 2½- by 6-foot trommel screen, with 1½-inch square openings, which removes the fines and rejects the oversize to a No. 836 Universal jaw crusher 24 by 36 inches in size. Crusher-run material is discharged to a 150-foot inclined conveyor belt leading upward to a 4- by 24-foot trommel screen on top of the bunkers where wash water is introduced. The trommel makes the following clean products: 0 to ⅜-inch, ⅜ to ¾-inch, ¾ to 1½-inch, and plus 1½-inch gravel. The 0 to ⅜-inch product is diverted to an adjacent drag classifier, about 6 by 12 feet in size, which subdivides the material into sand and 0 to ⅜-inch gravel. Three bunkers of 75-cubic yard, 100-cubic yard, and 125-cubic yard capacity receive the end products, and additional stocks are piled on the ground.

The plant is electrically operated with connected horsepower as follows: crusher, 12; feeder, 7; conveyor belt, 10; water pump, 7; trommel screen, 10; totaling 46 horsepower. Water for the plant is provided by a 140-foot well operated on a pump which requires an additional 45 horsepower.

Sorum and Gendreau quarry (Russell quarry) (46) is located approximately in the SE¼ sec. 9, T. 3 S., R. 2 W., M.D., behind the Hayward High School. It is owned by Hayward High School and operated by Sorum and Gendreau, of 1059 Havens Street, Hayward.

This quarry is operated on the property of Hayward High School and was formerly known as the Russell quarry. The present lessors have operated it for 1 year and plan to continue operations for an additional year, at which time the property will be used by the owner as as athletic field. The quarry face is about 175 feet high and 700 feet long. It is shot down and loaded by a ¼-yard-Bay City caterpillar mounted shovel powered by a McCormick-Deering engine. The truck haul is about 200 yards to a chute set with a 5- by 12-foot grizzly consisting of steel rails with 18-inch openings. Rock passes to a Straub Kue Ken jaw crusher run by a 15-horsepower motor. Crusher-run material is discharged to a 75-foot incline conveyor belt terminating at a stationary screen with 1½-inch openings making fines and oversize. The oversize consists of plus 1½-rock. Two tunnel loading truck bunkers have a capacity of 350 tons each. Three men are employed in this operation.

Superior Rock Company (Bilgers Property Company[82]) (47) is located in sec. 24, T. 2 S., R. 4 W., M. D. (projected), on McAdam Street, about half a mile east of Broadway.

This quarry has been in operation almost continuously since 1870 and was one of the largest in the Bay area. The Superior Rock Company began operations in 1938 after the quarry had been idle for about 7 years. The rock is a hard, fine-grained, blue-gray, metamorphosed sandstone of the Franciscan formation. The quarry was operated as an open pit. After blasting, the rock was shovel-loaded to trucks and hauled to the crushing plant. The products made were roofing granules, road rock, macadam, and riprap. About 15 men were employed annually until 1946, when the quarry was permanently closed.

Zaro gravel pit (48) is located approximately in the N½ sec. 21, T. 3 S., R. 1 E., M.D. (projected), a quarter of a mile east of Pleasanton on the south side of the Livermore highway. It is operated by A. C. Zaro, Box 323, Pleasanton.

The trench of Arroyo Valle runs south of the highway and parallel to it in this vicinity. At this location it is about 30 feet deep and 100 feet wide. Creek gravel is trucked to a 7- by 7-foot receiving hopper at the roadside and passes through a grizzly of steel rails with 4-inch openings where the oversize is removed manually.

The undersize is discharged to a low-angle 25-foot belt conveyor, operated by a 5-horsepower General Electric induction motor. The conveyor feeds a conical revolving screen, 2½ by 4 by 10 feet, operated by a 2-horsepower Crocker Wheeler electric motor. The screen separates ¼-inch, ½-inch, 1-inch, and oversize gravel (1- to 4-inch). These products are delivered by chute to the underlying storage bunkers from which trucks are loaded at creek level.

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[82] Laizure, C. McK, op. cit., p. 447, 1929.

Talc

Talc is a hydrous magnesium silicate, $H_2Mg_3(SiO_3)_4$. It is sometimes called soapstone or steatite. ''Talc'' includes all forms of the pure mineral; ''steatite'' denotes the massive, compact variety; ''soapstone'' includes the impure, massive variety, containing as little as 50 percent talc. Talc is an alteration product of magnesium minerals such as pyroxenes, amphiboles, and olivine. It is commonly found in such metamorphic rocks as schists and serpentine.

An occurrence of talc, as small seams in serpentine, was reported [83] in sec. 32, T. 4 S., R. 4 E. A small production of soapstone was reported in 1908 and 1910.

OPPORTUNITY FOR MINERAL STUDY

Many opportunities for the study of minerals, both professionally or as a hobby, are afforded the residents of Alameda County. Courses in geology, mineralogy, and related topics are offered at the following institutions of learning. The courses usually begin in August and January of each year.

University of California (day classes)
Berkeley, California

University Extension (evening classes)
University of California,
1730 Franklin St., Oakland 12, or
2441 Bancroft Way, Berkeley 4

University Extension (correspondence courses)
University of California,
1730 Franklin St., Oakland 12, or
2441 Bancroft Way, Berkeley 4

Oakland Technical High School (evening course)
42nd and Broadway, Oakland

Membership in the following mineral societies is open to persons interested in the study, collection, and exchange of minerals. Planned week-end field trips conduct members to known mineral localities in the vicinity.

Castro Valley Mineral Society,
Castro Valley, California

East Bay Mineral Society,
Lincoln School Auditorium (meeting place)
11th & Jackson Streets, Oakland
P. O. Box 1196, Oakland 4

The mineral museum of the California Division of Mines, Ferry Building, San Francisco, is world famous and contains a collection of more than 10,000 rare and unusual mineral specimens. It has been judged the best mineral museum west of the Mississippi River, and its gold collection is unexcelled in both beauty and diversity of mineral origin. This museum is open to the public without charge, daily during business hours.

Mineral collectors wishing to add to their personal collections may purchase mineral specimens from all over the world at the well-stocked stores of the following mineral dealers. These dealers also sell mineral text-books and some prospecting equipment.

Minerals Unlimited
1724 University Ave.
Berkeley, California

World Minerals
2417 San Pablo Ave.
Oakland, California

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[83] Aubury, Lewis C., The structural and industrial minerals of California: California Min. Bur. Bull. 38, p. 350, 1906.

TABULATED LIST OF PRINCIPAL MINES AND MINERAL DEPOSITS, ALAMEDA COUNTY, CALIFORNIA

Map No.	Name of deposit	Name of owner or operator	Location				Mineral product	Remarks and references *
			Sec.	T.	R.	B.&M.		
1	California Pottery Co.	California Pottery Co., Niles, Calif.	15	4S	1W	MD	Clay, ceramics	P. R. 7, p. 36; R. 17, p. 19; B. 99, p. 39.
2	N. Clark and Sons Div. Pacific Clay Products	Pacific Clay Products ,306 West Avenue 26, Los Angeles, Calif.	10	2S	4W	MD	Clay, ceramics	P. R. 7, p. 36; R. 17, p. 19; B. 99, p. 40.
3	California Rock and Gravel Co.	California Rock and Gravel Co., 1800 Hobart Bldg., San Francisco, Calif.	24	3S	1E	MD	Clay	
4	Gladding, McBean & Co.	Gladding, McBean & Co., 2901 Los Feliz Blvd., Los Angeles, Calif.	20	3S	3E	MD	Clay (shale)	
5	Interlocking Roof Tile Co.	J. Pessagno and Sons, Niles, Calif.	17	4S	1W	MD	Clay, ceramics	
6	Kraftile Co.	Kraftile Co., Niles, Calif.	18	4S	1W	MD	Clay, ceramics	B. 99, p. 41.
7	Henry J. Kaiser Co.	Henry J. Kaiser Co., 1924 Broadway, Oakland, Calif.	14	3S	1E	MD	Clay	
8	M. and S. Tile Co.	M. and S. Tile Co., Decoto, Calif.	1	4S	2W	MD	Clay, ceramics	B. 99, p. 41.
9	Tesla	W. G. and G. E. Wagoner, Livermore, Calif.	25	3S	3E	MD	Clay	R. 17, p. 22; R. 18, p. 185; R. 20, p. 324; R. 25, p. 433; B. 38, p. 206; B. 99, p. 43.
10	Ryan Ranch	Tesla Clay Co., c/o Isabel Bros., 75 W. Whittier Ave., Tracy, Calif.	26	3S	3E	MD	Clay	R. 25, p. 432; B. 99, p. 45; B. 38, p. 204.
11	Newman (Mendenhall)	Ralph F. Newman	26	4S	3E	MD	Chromite	R. 12, p. 36; R. 13, p. 48; R. 17, p. 23; R. 25, p. 435; B. 76, p. 115; B. 79, p. 41; B. 140, p. 59; U. S. G. S. B. 430, p. 173.
12	Tesla	W. G. & G. E. Wagoner, Livermore, Calif.	25	3S	3E	MD	Coal	R. 17, p. 22; R. 18, p. 185; R. 20, p. 324; R. 25, p. 433; B. 38, p. 206; B. 110, p. 17.
13	San Francisco Bay	Beck Dredging Co., 305 Parrott Drive, San Mateo, Calif.	21	5S	2W	MD	Lime (shells)	
14	Westvaco Chemical Div., Food Machinery and Chemical Corp.	Westvaco Chemical Div., Food Machinery and Chemical Corp., Newark, Calif.	11	5S	2W	MD	Magnesia and bromine	R. 25, p. 442.

TABULATED LIST OF PRINCIPAL MINES AND MINERAL DEPOSITS, ALAMEDA COUNTY, CALIFORNIA—Continued

Map No.	Name of deposit	Name of owner or operator	Location				Mineral product	Remarks and references *
			Sec.	T.	R.	B.&M.		
15	Cedar Mountain	Hugh Walker, Livermore, Calif	27	4S	3E	MD	Magnesite	R. 17, p. 23; R. 25, p. 435; B. 79, p. 41; U. S. G. S. B. 430, p. 173.
16	Man Ridge (Scott & Winegar, Elliott & Searles, Haecke)	Phil Winegar, Arthur Most	7	5S	4E	MD	Manganese ore	R. 17, pp. 26-28; R. 25, p. 436; B. 76, p. 28; B. 125, pp. 74, 100; B. 152, p. 23.
17	Nelson Lease (Bailey Newhall lease)	Holm Bros.	10	4S	3E	MD	Manganese ore	R. 17, p. 27; R. 25, p. 436; B. 76, p. 27; B. 125, pp. 74, 100; B. 152, p. 24.
18	Section 14	Lee Ogier (Phil Winegar lessee)	14	5S	3E	MD	Manganese ore	B. 125, pp. 74, 101; B. 152; p. 26.
19	Livermore Valley Oil Co.	Gatsmer Wagoner, Livermore, Calif.	15	3S	3E	MD	Petroleum	B. 118, p. 637; B. 140, p. 64.
20	Alma	Leota C Reed, 493 Merritt Ave., Oakland, Calif.	34	1S	3W	MD	Pyrite	R 17, p. 33; R. 25, p. 440; B. 23, p. 144; B. 50, p. 169.
21	Leona	Bank of America, 550 Montgomery St., San Francisco, Calif.	3	2S	3W	MD	Pyrite	R. 17, p. 33; R. 25, p. 440; B. 23, p. 144; B. 50, p. 170.
22	American Salt Co.	American Salt Co., Mt. Eden, Calif.	25	3S	3W	MD	Salt	R. 17, p. 33; R. 25, p. 443.
23	Leslie Salt Co.	Leslie Salt Co, Newark, Calif.	12	5S	2W	MD	Salt	R. 17, p. 34; R. 25, p. 443.
24	Morton Salt Co.	Morton Salt Co., Newark, Calif.	12	5S	2W	MD	Salt	R. 25, p. 445.
25	Oliver Bros. Salt Co.	Oliver Bros. Salt Co., Mt. Eden, Calif.	31	3S	2W	MD	Salt	R. 17, p. 35; R. 25, p. 443.
26	Tesla Sand & Clay Co.	G. G. Sanders, Mills Bldg., San Francisco, Calif.	25	3S	3E	MD	Molding sand	R. 44, p. 48.
27	Ashland Rock and Material Co.	Cliff Mankins, 7735 San Leandro St., Oakland, Calif.	5	3S	2W	MD	Crushed rock	
28	Bell Sand and Gravel	Bell Sand and Gravel, Box 282, Irvington, Calif.	2	5S	1W	MD	Sand and gravel	
29	Buranis Bros. & Co.	Buranis Bros. & Co., Livermore, Calif.	16	3S	2E	MD	Sand and gravel	
30	California Rock and Gravel Co.	California Rock and Gravel Co., 1800 Hobart Bldg., San Francisco, Calif.	24	3S	1E	MD	Sand and gravel	

31	Castro Valley Rock Co.	B. F. Garofals, 20450 John St., Hayward, Calif.	9	3S	2W	MD	Crushed rock	
32	Concrete Materials Co.	W. C. Thompson, 1401 Illinois St., San Francisco, Calif.	15	3S	1E	MD	Sand and gravel	
33	Goddard Bros.	Goddard Bros., 187 Sunset Blvd., Hayward, Calif.	26	3S	2W	MD	Crushed rock	
34	Heafy-Moore Co.	Heafy-Moore Co., 344 High St., Oakland, Calif.	2-11	2S	3W	MD	Crushed rock	R. 25, p. 449.
35	Inland Aggregates Co., Inc.	Inland Aggregates Co., Inc., Niles, Calif.	20	4S	1W	MD	Sand and gravel	
36	Henry J. Kaiser Co.	Henry J. Kaiser Co., 1924 Broadway, Oakland, Calif.	21	4S	1W	MD	Sand and gravel	
37	Henry J. Kaiser Co.	Henry J. Kaiser Co., 1924 Broadway, Oakland, Calif.	15	3S	1E	MD	Sand and gravel	R. 25, p. 450.
38	Macco Construction Co., 815 N. Paramount Blvd., Clearwater, Calif.	Bothin Co., 604 Mission St., San Francisco, Calif.	18	2S	3W	MD	Crushed rock	
39	Niles Quarry	C. C. Sawyer, 4061 Highland Blvd., Hayward, Calif.	17	4S	1W	MD	Crushed rock	
40	Pacific Coast Aggregates, Inc., Plant No. 106	Pacific Coast Aggregates, Inc., 400 Alabama St., San Francisco, Calif.	19	4S	1W	MD	Sand and gravel	
41	Pacific Coast Aggregates, Inc., Plant No. 104	Pacific Coast Aggregates, Inc., 400 Alabama St., San Francisco, Calif.	14	3S	1E	MD	Sand and gravel	R. 25, pp. 451-455.
42	Pacific Coast Aggregates, Inc., Plant No. 105	Pacific Coast Aggregates, Inc., 400 Alabama St., San Francisco, Calif.	21	4S	1W	MD	Sand and gravel	R. 25, pp. 451-455.
43	Picard	A. B. Picard, 300 St. Mary's Ave., Pleasanton, Calif.	17	3S	1E	MD	Sand and gravel	
44	San Leandro Rock Co.	San Leandro Rock Co., 1575 Lake Chabot Road, San Leandro, Calif.	30	2S	2W	MD	Crushed rock	R. 17, p. 38; R. 25, p. 455.
45	Silva Bros.	Herman & Lauren Silva, 1662 Bridge St., Hayward, Calif.	22	4S	1W	MD	Sand and gravel	
46	Sorum & Gendreau	Sorum & Gendreau, 1059 Havens St., Hayward, Calif.	9	3S	2W	MD	Crushed rock	R. 25, p. 455.
47	Superior Rock Co.	Norman Ogilvie & Co., 528 18th St., Oakland, Calif.	24	1S	4W	MD	Crushed rock	R. 11, p. 125; R. 12, p. 388; R. 13, p. 644; R. 17, p. 39; R. 25, p. 447; B. 38, p. 312.

TABULATED LIST OF PRINCIPAL MINES AND MINERAL DEPOSITS, ALAMEDA COUNTY, CALIFORNIA—Continued

Map No.	Name of deposit	Name of owner or operator	Location				Mineral product	Remarks and references *
			Sec.	T.	R.	B.&M.		
48	Zaro	A. C. Zaro, Box 323, Pleasanton, Calif.	21	3S	1E	MD	Sand and gravel	
49	John D. Hoff Asbestos Co.		36(?)	1S	3W	MD	Asbestos	R. 25, p. 430.
50	Clark (Vernon)	Ralph F. Newman, Maud I. Wagner, Box 114, Alamo, Calif.	26	4S	3E	MD	Chromite	B. 76, p. 115; R. 17, p. 20; R. 25, p. 433.
51	Douglass	Gerald F. Lafon, 210 South M St., Livermore, Calif.	26	4S	3E	MD	Chromite	R. 8, p. 32; R. 12, p. 36; R. 13, p. 48; R. 17, p. 20; B. 38, p. 266.
52	Dragi	O. E. Biel, Star Route, Livermore, Calif.	18	5S	4E	MD	Chromite	Min. Res. 1918, p. 661 (small prod. 1918).
53	Jones		6	5S	4E	MD	Chromite	B. 38, p. 267; Min. Res. 1908, p. 767.
54	California rick Co. (W. S. Dickey)	Pacific States Steel Co., Niles, Calif.	18	4S	1W	MD	Clay	R. 17, pp. 18-20; R. 25, p. 431; B. 99, p. 40; P. R. 7, pp. 35-37.
55	Carnegie Brick & Pottery Co.	Gladding, McBean Co., 2901 Los Feliz Blvd., Los Angeles, Calif.	30	3S	4E	MD	Clay	B. 38, p, 202; B. 99, p. 45.
56	Remillard Brick Co.	Remillard-Dandini Co., 400 Montgomery St., San Francisco, Calif.	15	3S	1E	MD	Clay	R. 8, p. 342; R. 11, pp. 126-254-375; R. 12, p. 381; R. 13, pp. 613-615-618; R. 14, p. 248; R. 17, p. 20; R. 25, p. 432; P. R. 7, p. 37; B. 38, p. 242; B. 99, p. 42.
57	Almaden	W. G. & G. E. Wagoner, Livermore, Calif.	25	3S	3E	MD	Coal	R. 7, p. 147; U. S. G. S. Rpt. 22, Pt. 3, p. 502.
58	Coleman	W. G. & G. E. Wagoner, Livermore, Calif.	26	3S	3E	MD	Coal	R. 8, p. 28.
59	Commercial	W. G. & G. E. Wagoner, Livermore, Calif.	25	3S	3E	MD	Coal	R. 7, p. 147; U. S. G. S. Rpt. 22, Pt. 3, p. 502.
60	Livermore Coal Co.	W. G. & G. E. Wagoner, Livermore, Calif.	27	3S	3E	MD	Coal	R. 8, pp. 26 28; R. 7, p. 147; R. 10, pp. 91-95; U. S. G. S. Rpt. 22, Pt. 3, p. 502; B. 140, p. 61.
61	Pendarin	W. G. & G. E. Wagoner, Livermore, Calif.	26	3S	3E	MD	Coal	R. 8, p. 26; R. 10, p. 92.
62	Unnamed	John Flynn, Rt. 1, Box 133, Tracy, Calif.	30	3S	4E	MD	Coal	B. 140, p. 61.

63	Unnamed	Flynn Bros., Rt. 1, Box 133, Tracy, Calif.	32	3S	4E	MD	Coal	B. 140, p. 61.
64	J. D. Collins	Sue I. Nissen, 1080 Fourth St., Livermore, Calif.	30	2S	3E	MD	Limestone	R. 38, p. 64.
65	McLaughlin Lithographic Stone	R. & A. Mueller, 2247 Havenscourt Blvd., Oakland 5, Calif.	35	1S	2W	MD	Limestone	R. 25, p. 433.
66	Mission Lime Marl		1	5S	1W	MD	Agricultural lime	R. 8, p. 35; R. 20, p. 184; R. 25, p. 434.
67	Pleasanton Lime & Cement Co.		33(?)	3S	1E	MD	Agricultural lime	R. 17, p. 22; R. 25, p. 434; U. S. G. S. Rpt. 22, Pt. 3, p. 501.
68	Unnamed		10	3S	3E	MD	Travertine	B. 140, p. 62.
69	Unnamed	Flynn Bros., Rt. 1, Box 133, Tracy, Calif.	32	3S	4E	MD	Lime rock	B. 140, p. 62.
70	Banta's Camp	Otto E. Biel, Star Route, Livermore, Calif.	16	5S	4E	MD	Magnesite	U. S. G. S. B. 355, p. 37.
71	Hayes Ranch	Edward T. Sachu, P. O. Box 563, Livermore, Calif.	24	4S	2E	MD	Magnesite	R. 17, p. 24; R. 25, p. 435; B. 79, p. 42.
72	King Claim		8	5S	4E	MD	Magnesite	B. 38, p. 327.
73	Winship properties	K. D. Winship Estate, 350 Post St., San Francisco, Calif.	34-35	4S	3E	MD	Magnesite	R. 25, p. 435; B. 79, p. 42; U. S. G. S. B. 430, p. 173.
74	Bartlett	P. & P. J. Connolly	6	4S	4E	MD	Manganese ore	R. 13, p. 506; R. 12, p. 329; R. 11, p. 121; B. 38, p. 335; B. 125, p. 97; B. 152, p. 15.
75	Beraudiere	Leslie Holm, et al., Rt. 1, Box 6, Livermore, Calif.	NW14	4S	3E	MD	Manganese ore	R. 25, p. 436; R. 17, p. 24; B. 76, p. 25; B. 125, p. 97; B. 152, p. 15.
76	Black Jack	Leslie Holm, et al., Rt. 1, Box 6, Livermore, Calif.	NE14	4S	3E	MD	Manganese ore	R. 25, p. 436; R. 17, p. 25; R. 13, p. 506; B. 76, p. 25; B. 38, p. 335; B. 125, p. 97; B. 152, p. 16.
77	Buckhorn	Oakland Area Council, Boy Scouts of America, P.O. Box 796, Oakland, Calif.	31	4S	4E	MD	Manganese ore	R. 25, p. 436; R. 17, p. 25; B. 76, p. 25; B. 125, p. 97; B. 152, p. 16.
78	Camp 9 (Merchant, Cummings)	M. K. Devany & John Kelly, 291 Junction Ave., Livermore, Calif.	9	4S	3E	MD	Manganese ore	R. 25, p. 436; R. 17, p. 25; R. 13, p. 506; R. 12, p. 329; B. 76, p. 26; B. 38, p. 335; B. 125, p. 97; B. 152, p. 17.
79	Cheny lease (Winship, Donovan, Doak)	Frank J. Rodriguez, Star Route, Box 5, Livermore, Calif.	NE12	4S	3E	MD	Manganese ore	R. 25, p. 437; R. 17, p. 28; B. 76, p. 28; B. 125, p. 97; B. 152, p. 18.
80	Corral Hollow		22(-)	4S	3E	MD	Manganese ore	R. 13, p. 506; B. 38, p. 367; B. 125, p. 98; B. 152, p. 19.
81	Crosby	Mary Gerow, et al.	SW30	4S	3E	MD	Manganese ore	R. 25, p. 436; R. 17, p. 26; B. 76, p. 26; B. 125, p. 98; B. 152, p. 19.
82	Dewhirst	Mabel Newman, 1196 18th St., Oakland, Calif.	SW22	4S	3E	MD	Manganese ore	R. 25, p. 436; R. 17, p. 26; B. 76, p. 26; B. 125, p. 98; B. 152, p. 19.

TABULATED LIST OF PRINCIPAL MINES AND MINERAL DEPOSITS, ALAMEDA COUNTY, CALIFORNIA—Continued

Map No.	Name of deposit	Name of owner or operator	Location				Mineral product	Remarks and references *
			Sec.	T.	R.	B.&M.		
82	Dragi	Otto E. Biel, Star Route, Livermore, Calif.	18	5S	4E	MD	Manganese ore	B. 140, p. 66; B. 125, p. 98.
83	Dyer		17	2S	3E	MD	Manganese ore	B. 125, p. 98; B. 152, p. 20.
84	Ellis Ranch		28	3S	3E	MD	Manganese ore	R. 25, p. 436; R. 17, p. 26; B. 76, p. 26; B. 125, p. 98; B. 152, p. 20.
85	Foscilina	Alameda County Title Insurance Co., Attn. Heckman, 1034 Filbert St., San Francisco, Calif.	SW8	5S	4E	MD	Manganese ore	B. 140, p. 66; B. 125, p. 98.
86	Freitas	Wm. Freitas	8	4S	3E	MD	Manganese ore	R. 25, p. 436; R. 17, p. 27; R. 13, p. 506; R. 12, p. 329; B. 76, p. 27; B. 38, p. 335; B. 125, p. 99; B. 152, p. 21.
87	Friggel	Arthur A. Holm, 529 South L St., Livermore, Calif.	NW22	4S	3E	MD	Manganese ore	R. 25, p. 436; R. 17, p. 27; B. 76, p. 27; B. 125, p. 99; B. 152; p. 21.
88	Gallagher	Dan Gallagher, 637 Beacon St., Livermore, Calif.	13 19	4S 4S	3E 4E	MD	Manganese ore	B. 125, p. 99; B. 152, p. 21.
89	Graves (Grey Fox)	Otto E. Biel, Star Route, Box 28, Livermore, Calif.	7, 18 12	5S 5S	4E 3E	MD	Manganese ore	B. 125, p. 99; B. 152, p. 21.
90	Hearst		30	4S	4E	MD	Manganese ore	R. 13, p. 506; B. 125, p. 99; B. 152, p. 21.
91	Jumbo	Leslie Holm, et al., Rt. 1, Box 6, Livermore, Calif.	NE14	4S	3E	MD	Manganese ore	B. 76, p. 27; B. 125, p. 100; B. 152, p. 21.
92	Kelly	John M. Kelly & May K. Devany, 291 Junction Ave., Livermore, Calif.	5	4S	3E	MD	Manganese ore	R. 25, p. 436; R. 17, p. 27; B. 76, p. 27; B. 125, p. 100; B. 152, p. 22.
93	Mendenhall	F. J. Rodriguez, Star Route, Box 5, Livermore, Calif.	NE12	4S	3E	MD	Manganese ore	R. 13, p. 506; R. 12, p. 329; B. 125, p. 100; B. 152, p. 24.
94	Newman (Estacia)	Mabel Newman, 1196 18th St., Oakland, Calif.	22	4S	3E	MD	Manganese ore	R. 25, p. 436; R. 17, p. 27; R. 13, p. 506; R. 12, p. 329; B. 76, p. 27; B. 38, p. 335; B. 125, p. 101; B. 152, p. 25.
95	Reay	Fred Shidaker, 315 S. Livermore Ave., Livermore, Calif.	36	3S	3E	MD	Manganese ore	R. 25, p. 437; R. 17, p. 27; B. 76, p. 28; B. 125, p. 101; B. 152, p. 25.

96	Root	Otto E. Biel, Star Route, Box 28, Livermore, Calif.	7 or 18	5S	4E	MD	Manganese ore	R. 25, p. 437; R. 17, p. 27; B. 76, p. 28; B. 125, p. 101; B. 152, p. 26.
97	Taylor and Pitcher	Mary I. Berk, et al., Fourth and J Sts., Livermore, Calif.	app. 1	4S	3E	MD	Manganese ore	R. 13, p. 506; R. 12, p. 329; B. 125, p. 101; B. 152, p. 26.
98	Winegar		4	5S	4E	MD	Manganese ore	R. 25, p. 437; R. 17, p. 28; B. 76, p. 28; B. 125, p. 101; B. 152, p. 26.
99	Langdon Bros.		11	4S	2W	MD	Silica (molding sand)	R. 25, p. 439.
100	Unnamed	W. G. & G. E. Wagoner, P.O. Box 294, Livermore, Calif.	26	3S	3E	MD	Silica (molding sand)	B. 140, p. 61.
101	Unnamed	Flynn Bros., Rt. 1, Box 133, Tracy, Calif.	32	3S	4E	MD	Silica (molding sand)	B. 140, p. 61.
102	Altamont Quarry	E. & A. Hartman, Rt. 1, Box 239, Livermore, Calif.	28	2S	3E	MD	Sandstone (building)	R. 8, p. 34-891; R. 11, p. 122; B. 38, p. 116.
103	Farwell's Sandstone Quarry	A. L. & M. P. Juhl, Niles, Calif.	11	4S	1W	MD	Sandstone (building)	R. 8, p. 35; R. 9, p. 122; R. 12, p. 388; R. 13, p. 635; B. 38, p. 117.
104	Alves Quarry	Alves Quarry, Central Ave. & Delmar St., Hayward, Calif.	22	3S	2W	MD	Crushed rock	
105	Andrade & Pexioto	Andrade & Pexioto, 28806 Niles Road, Hayward, Calif.	app. 35	3S	2W	MD	Crushed rock	
106	Louis Angeles	Louis Angeles, 604½ MacArthur Blvd., San Leandro, Calif.	24	2S	3W	MD	Crushed rock	
107	Ariss-Knapp Co.	Ariss-Knapp Co., 961 41st St., Oakland, Calif.	app. 18	1S	3W	MD	Crushed rock	
108	Casson Co.	Virginia C. Hauschildt, 21311 Montgomery Ave., Hayward, Calif.	app. 22	3S	2W	MD	Crushed rock	
109	J. Catucci	B. Catucci, 6110 Telegraph Ave., Oakland, Calif.	app. 14	2S	3W	MD	Crushed rock	
110	Leslie Salt Co.	Leslie Salt Co., 310 Sansome St. San Francisco, Calif.	3	5S	2W	MD	Crushed rock	
111	McLean Red Shale	Leslie Holm, et al., Rt. 1, Box 6, Livermore, Calif.	14	4S	3E	MD	Crushed rock	R. 25, p. 437; B. 140, p. 62.
112	J. L. Martin	J. L. Martin, 5921 Shepherd Canyon Road, Oakland, Calif.	app. 21	1S	3W	MD	Crushed rock	
113	Sunol Road Quarry	Custodio Escobar	25	4S	1W	MD	Crushed rock	B. 38, p. 315.

TABULATED LIST OF PRINCIPAL MINES AND MINERAL DEPOSITS, ALAMEDA COUNTY, CALIFORNIA—Continued

Map No.	Name of deposit	Name of owner or operator	Location				Mineral product	Remarks and references *
			Sec.	T.	R.	B.&M.		
114	Vargas Quarry		app. 26	3S	2W	MD	Crushed rock	
	Numerous old quarries		Unlocated				Crushed rock	R. 8, p. 35; B. 38, pp. 311-314.
115	Garcia Bros.	Garcia Bros., Durham Road, Irvington, Calif.	app. 2	5S	1W	MD	Sand and gravel	
116	Henry J. Kaiser Co.	Henry J. Kaiser Co., 1924 Broadway St., Oakland, Calif.	17	3S	2E	MD	Sand and gravel	
117	Ritchie	Ritchie Sand and Gravel, Pleasanton, Calif.	17	3S	1E	MD	Sand and gravel	
118	Wente Pit	E. A. Wente, P.O. Box 471, Livermore, Calif.	15-22	3S	2E	MD	Sand and gravel	
119	Gray Eagle	Carlo Ferrario, 1210 Third St., Livermore, Calif.	32	4S	4E	MD	Talc	B. 38, p. 350.
120	Copeland	W. G. & G. E. Wagoner, Livermore, Calif.	27	3S	3E	MD	Volcanc tuff	R. 25, p. 431; B. 140, p. 67.

* R=Report; B=Bulletin; P.R.=Preliminary Report published by California State Division of Mines.

DIVISION OF MINES PUBLICATIONS ISSUED MAY 1, 1949 TO JANUARY 1, 1950

BULLETINS

118. (Reprint) Geologic formations and economic development of the oil and gas fields of California, prepared under the direction of Olaf P. Jenkins. 1943. 773 pp., 6 pls., 1 map, 81 index maps, 296 figs. Price $6.00.

Contains: Part 1, Development of the industry; Part 2, Geology of California and the occurrence of oil and gas; Part 3, Descriptions of individual oil and gas fields; Part 4, Glossaries, bibliography, and index; Outline geologic map of California showing oil and gas fields and drilled areas (Economic mineral map of California no. 2—Oil and gas), scale 1:1,000,000.

123. (Reprint) American mining law, with forms and precedents, by A. H. Ricketts. 1943. Vol. 1, pp. i-xxxi, 1-618; vol. 2, pp. 619-1018. Price $3.00.

142. The counties of California—mineral resources and mineral production. 1949. 197 pp., 1 fig., 12 pls., 54 tables. Price, paper-bound, $1.25; cloth-bound, $2.00.

(California residents please add 3% sales tax.)

CALIFORNIA JOURNAL OF MINES AND GEOLOGY

Vol. 45, no. 3, July 1949, pp. 359-502, pls. 19-23, 3 figs. Price 75¢.

Contains: Water-flooding as a method of increasing California oil production (Part 2, A survey of California conditions relative to the application of water-flooding), by Wilbur H. Somerton, pp. 363-416; Mines and mineral resources of Butte County, California, by J. C. O'Brien, pp. 417-454, pls. 19-23; Roofing granules in the southwest, by Stuart H. Ingram, pp. 455-458; The western pulp and paper industry as a consumer of chemicals, by R. G. Mispley, pp. 459-464; Mining law in recent years, by William E. Colby, pp. 465-490; Ione-Carbondale clays, Amador County, California, by F. T. Johnson and Spangler Ricker, pp. 491-498, 3 figs.; Address of Governor Earl Warren to the American Institute of Mining and Metallurgical Engineers, Inc., pp. 499-502.

The following is included with report, or may be purchased separately: Map of Butte County, showing location of mines and prospects, scale 1″ = 3 mi.; price 25¢.

Vol. 45, no. 4, October 1949, pp. 503-590, pls. 24-26, 2 figs. Price $1.00.

Contains: Geology of limestone near Sonora, Tuolumne County, California, by George R. Heyl and John H. Wiese, pp. 509-513; Geology of limestone near Gazelle, Siskiyou County, California, by George R. Heyl and George W. Walker, pp. 514-520, 2 figs.; Minerals of California—Supplement No. 1 to Bulletin 136, by Joseph Murdoch, pp. 521-540; Water-flooding as a method of increasing California oil production (Part 3, Current and proposed water-flooding research in California), by Wilbur H. Somerton, pp. 541-551; Materials of inorganic mineral origin used in the rubber industry, by Erle C. Zimmerman, pp. 553-561; Index to volume 45, pp. 563-590; Supplement, The elephant as they saw it, by Elisabeth L. Egenhoff, pp. 1-128, 66 figs.

The following is included with report, or may be purchased separately: The elephant as they saw it, by Elisabeth L. Egenhoff, pp. 1-128, 66 figs. Price 75¢.

Vol. 46, no. 1, January 1950, pp. 1-184, pls. 1-22, 9 figs. Price $1.00.

Contains: Submarine phosphorite deposits off California and Mexico, by K. O. Emery and R. S. Dietz, pp. 7-16; Geology along the Electra and West Point tunnels, Amador County, California, by John H. Wiese, Arvid A. Stromquist, John H. Eric, and C. Melvin Swinney, pp. 17-22, 1 fig.; Geology and tungsten deposits of the Tungsten Hills, Inyo County, California, by Paul C. Bateman, Max P. Erickson, and Paul D. Proctor, pp. 23-42, 3 figs.; Geology of the Placerita oil field, Los Angeles County, California, by Gordon B. Oakeshott, pp. 43-80, 3 figs.; Perlite deposits in Sonoma County, California, by Charles W. Chesterman, pp. 81-82; Mines and mineral resources of Sonoma County, California, by Martin T. Honke Jr. and William E. Ver Planck Jr., pp. 83-142, 2 figs.; Annual report of the state mineralogist, Chief of the Division of Mines, for the one hundredth fiscal year, July 1, 1948 to June 30, 1949, pp. 143-184.

The following is included with report, or may be purchased separately: Map of Mines and Mineral Deposits of Sonoma County, California; price 25¢.

SPECIAL PUBLICATIONS

20. The elephant as they saw it: a collection of contemporary pictures and statements on gold mining in California, assembled by Elizabeth L. Egenhoff as a centennial supplement to the California Journal of Mines and Geology for October 1949. 128 pp., 70 illus., colored frontis. Price 75c.

21. Manner of locating and holding mineral claims in California, by A. H. Ricketts, revised by C. A. Logan and Charles V. Averill, supplement to the California Journal of Mines and Geology for April 1950. 31 pp. Price 50c; free with purchase of $1.00 worth of publications.

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STATE OF CALIFORNIA
EARL WARREN, Governor
DEPARTMENT OF NATURAL RESOURCES
WARREN T. HANNUM, Director

DIVISION OF MINES

FERRY BUILDING, SAN FRANCISCO
OLAF P. JENKINS, Chief

Preprint of supplement to California Journal of Mines and Geology,
volume 46, number 2, April 1950

Manner of Locating and Holding Mineral Claims in California

By A. H. RICKETTS, Revised by C. A. LOGAN
and CHARLES V. AVERILL

printed in CALIFORNIA STATE PRINTING OFFICE

MANNER OF LOCATING AND HOLDING MINERAL CLAIMS IN CALIFORNIA*

By A. H. Ricketts
(with revisions by C. A. Logan and Charles V. Averill)

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* These notes are based upon *American Mining Law*, by A. H. Ricketts, State Division of Mines Bulletin 98, 1931 (republished as Bulletin 123, 1934), and briefly outline the salient information needed by the average prospector and claim owner in initiating and maintaining his possessory rights to mineral ground.

LANDS OPEN TO LOCATION

(Sec. 2319, Revised Statutes of U. S.)

All valuable mineral deposits in land belonging to the United States, both surveyed and unsurveyed, and the lands in which they are found, are free and open to exploration, occupation and purchase, except that aliens may not obtain patent. This includes mineral land within a national forest, the unpatented parts of a congressional grant to a railroad company (except iron and coal), or of an unconfirmed Mexican grant (to abide the final determination of the validity of the grant), also land within the limits of an unpatented townsite, or when known to be mineral at the date of the application for patent therefor, or an unlocated or unpatented "known lode" within the exterior limits of a patented or unpatented placer mining claim [1] or mineral lands within an abandoned military or Indian reservation or mineral lands restored to the public domain.

Land valuable for its mineral deposits is land which contains minerals in sufficient quantities to justify exploitation and development. The mineral deposits may be metalliferous such as gold, silver, and other metals, or nonmetalliferous such as alum, amber, building stone, diamonds, gypsum and like substances; but under more or less recent congressional legislation, popularly known as the "Leasing Act," lands known to contain coal, petroleum, oil shale, potash, phosphate, sodium salts (except common salt, on which one claim only may be located) can not be located nor patented under the lode or placer laws but are obtainable under lease, subject to the regulations and control of the Secretary of the Interior. But the possessory right to a location made prior to the passage of that act is not disturbed by its provisions.

Under the "Stock-Raising Homestead Act" there is a severance of the surface and mineral deposits and the latter may be located and worked in accordance with the mineral land law, with the right to enter and occupy so much of the surface thereof as may be required for all purposes reasonably incident to the mining or removal of the mineral; first, upon securing the written consent or waiver of the homestead entryman or patentee; second, upon the payment of damages to crops or other tangible improvements to the owner thereof, where agreement may be had as to the amount thereof, or, third, in lieu of either of the foregoing provisions he must execute a good and sufficient bond or undertaking to the United States for the use and benefit of entryman or owner of the land to secure the payment of damages to said crops and tangible improvements as may be determined by a court upon proceedings duly had and taken. All this seems to be giving a thing with one hand and taking it away with the other.

LANDS NOT OPEN TO LOCATION

Land is not subject to mineral location when lying within a subsisting Indian, military, naval, national park, national monument (except Death Valley National Monument), reservoir reservation, power site, when withdrawn from sale by authority of congress, or by an executive order express or implied; when situated below high tide; the bed of a navigable river; a lake bed (except Searles Lake in San Bernardino

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[1] But no one may go upon a valid placer claim to search for a vein, without the claim owner's permission.

County); coal or iron lands within the limits of a congressional land grant to a railroad company, or within its rights of way, or its indemnity limits; land within the limits of a congressional land grant to a state after approval of survey or certification by the land department; land which is occupied under color of title (unless it can be done peaceably); land which has passed into private ownership, patented land deeded to the state for unpaid taxes, land in national forests acquired under the Act of March 1, 1911 (Weeks Act); and land in a patented townsite after application for such patent has been made.

MINING CLAIMS WITHIN NATIONAL FORESTS

Generally speaking vacant United States land within the boundaries of national forests is open to location and entry for mining purposes under the general mining laws, subject to the jurisdiction of the United States Forest Service. There is much doubt and confusion as to the extent of this jurisdiction. Over certain lands (e.g., those obtained under the Weeks Act) jurisdiction is definite, and mining claims cannot be located on such land, but the Secretary of Agriculture is authorized, under regulations prescribed by him, to permit prospecting or mining there. All prospectors in the national forests should acquaint themselves with the Forest Service regulations. In general, the Forest Service is concerned primarily with preservation and improvement of forests, watersheds and range lands, and in California especially, with its long dry season, attention is given largely to fire prevention, through control of access to certain areas and control of use of explosives, fire permits, etc.

The trend of court decisions in disputes between the Forest Service and bona fide mineral locators has been to protect the miner in the full use and enjoyment of his claim. He should be prepared, however, to prove by definite assays, sampling or actual production records that the land embraced in his claim is not merely mineral-bearing, but is or promises to be more valuable for mining than for any other purpose. This is made necessary by the present policy of the Forest Service.

MINING LOCATIONS

A lode location can legally cover only a vein of quartz or other rock in place, and a placer location covers all other types of mineral deposit. Although either type of location if legally completed is presumed to give exclusive right to the surface except in special cases, there is no legal prohibition against the placing of both lode and placer locations on the same land by one locator, if conditions warrant. An example would be a partly eroded gold lode where the soil might carry free gold and the lode might be exposed by placer mining. Errors of any kind in a location which might render it void may be corrected by an amended location, in the absence of any intervening right. A "known lode" in a placer claim, if not specifically mentioned by the applicant for placer patent, and paid for separately, would become thereafter subject to lode location by another if this can be done peaceably, but blind veins pass to the placer claimant, without extralateral rights. No person may enter and prospect for such veins without the consent of the placer claimant.

A mill-site may be located on not over 5 acres of nonmineral land, not adjacent to a vein or lode, or it may be located or may be "scripped" upon lands which are prima facie mineral but which in fact are valueless as such.

A tunnel-site claim may be located for the purpose of prospecting for blind veins not previously known to exist along the location line of the tunnel, for a maximum length of 3000 feet. The locator has the exclusive right to prospect for such blind veins along the tunnel's course and to locate 1500 feet in length upon any such vein that is cut or discovered in the tunnel.

In general, there are no hard and fast forms that must be used in locating claims and a location notice written in pencil will be as valid as any other, if the essential requirements are met. Examples of forms are shown herein for all four classes of claims mentioned above, and these may be safely followed. A valid mining location can be made upon a Sunday or holiday. Witnesses are not required, although of course there are occasions when it may be desirable to have them.

CONFLICTING LOCATIONS

The principle which governs the conflicting claims of appropriators of mining claims and other rights on the public domain is that, other things being equal, the prior locator prevails. A location made within the limits of ground already appropriated is void from the beginning; but the boundary marks of lode locations may be placed upon or across the surface of a prior location, or intervening ground whether patented or unpatented as mining or agricultural ground, for the purpose of securing an extralateral right; but no right is given to the ground within the overlap. If a locator should happen by mistake to place some of the monuments necessary to mark out his boundaries upon another's claim, the location is valid so far as that portion of the ground which was open to location.

GOOD FAITH

Good faith, as an element in the initiation of mining rights under federal and state laws, is absolutely essential to the validity of such rights, may not be dispensed with, and lack of it vitiates any attempt to initiate such rights.

VOID LOCATIONS

Some instances of void locations are these: A location based upon a discovery which is within the boundaries of a prior claim; when located upon the dip of the vein or lode; a lode location of a placer deposit, or vice versa; a placer location intended to secure a known vein therein; to secure the timber growing thereon; a provisional location; a location or relocation based upon a breach of trust, or based upon trespass; a location without discovery where no attempt is made to discover the same; a discovery without boundaries; or, failure or neglect to comply with the local law in making the location on the ground.

ESSENTIAL ELEMENTS IN LOCATING MINING CLAIMS

The essential elements in locating either lode or placer claims are: discovery of mineral, marking the boundaries, posting the notice of location and the recording of an exact copy of same. The location notice *must* contain the following: (1) date; (2) name of locator or locators; (3) name of the claim; (4) the number of linear feet claimed in length along the course of the vein, each way from the point of discovery (in the case of a lode location) or the number of feet or acreage claimed (in the case of a placer claim); and (5) distance and direction as nearly as practicable from the discovery point to some permanent, well-known point, natural object or monument such as the confluence of streams, a bridge, hill or road intersection, except in the case of a placer claim located and described in the notice by legal subdivisions, where no other tie-in is needed. The location notice should be posted at the discovery point and it is customary to protect it from the elements in a box, tin can or cairn in plain view.

FEDERAL STATUTES ON MINING LOCATIONS

Title XXXII, Chapter VI, Revised Statutes of the United States, Sections 2318, 2319, 2320, 2321, 2322, 2323, and 2324 are the basic provisions under which all rights to mineral deposits in vacant United States land may be acquired in "public land states" such as California. No state law nor local custom of miners may give more than is allowed under federal statute; but such local laws may, and often have, limited these rights by prescribing the number or size of claims, or by placing added burdens upon locators. The above listed sections of the federal statutes are here given verbatim.

Sec. 2318. In all cases lands valuable for minerals shall be reserved from sale, except as otherwise expressly directed by law.

Sec. 2319. All valuable mineral deposits in lands belonging to the United States, both surveyed and unsurveyed, are hereby declared to be free and open to exploration and purchase, and the lands in which they are found to occupation and purchase, by citizens of the United States and those who have declared their intention to become such, under regulations prescribed by law, and according to the local customs or rules of miners in the several mining districts, so far as the same are applicable and not inconsistent with the laws of the United States.

Sec. 2320. Mining claims upon veins or lodes of quartz or other rock in place bearing gold, silver, cinnabar, lead, tin, copper, or other valuable deposits, heretofore located, shall be governed as to length along the vein or lode by the customs, regulations, and laws in force at the date of their location. A mining claim located after the tenth day of May, eighteen hundred and seventy-two, whether located by one or more persons, may equal, but shall not exceed, one thousand five hundred feet in length along the vein or lode; but no location of a mining claim shall be made until the discovery of the vein or lode within the limits of the claim located. No claim shall extend more than three hundred feet on each side of the middle of the vein at the surface, nor shall any claim be limited by any mining regulation to less than twenty-five feet on each side of the middle of the vein at the surface, except where adverse rights existing on the tenth day of May, eighteen hundred and seventy-two, render such limitation necessary. The end lines of each claim shall be parallel to each other.

Sec. 2321. Proof of citizenship under this chapter, may consist, in the case of an individual, of his own affidavit thereof; in the case of an association of persons unincorporated, of the affidavit of their authorized agent, made on his own knowledge or upon information and belief; and in the case of a corporation organized under the laws of the United States, or of any state or territory thereof, by the filing of a certified copy of their charter or certificate of incorporation.

Sec. 2322. The locators of all mining locations heretofore made or which shall hereafter be made, on any mineral vein, lode, or ledge, situated on the public domain, their heirs and assigns, where no adverse claims exist on the tenth day of May, eighteen hundred and seventy-two, so long as they comply with the laws of the United States, and with state, territorial and local regulations not in conflict with the laws of the United States governing their possessory title, shall have the exclusive right of possession and enjoyment of all the surface included within the lines of their locations, and of all veins, lodes, and ledges throughout their entire depth, the top or apex of which lies inside of such surface lines extended downward vertically, although such veins, lodes, or ledges may so far depart from a perpendicular in their course downward as to extend outside the vertical side lines of such surface locations. But their right of possession to such outside parts of such veins or ledges shall be confined to such portions thereof as lie between vertical planes drawn downward as above described, through the end lines of their locations, so continued in their own direction that such planes will intersect such exterior parts of such veins or ledges. And nothing in this section shall authorize the locator or possessor of a vein or lode which extends in its downward course beyond the vertical lines of his claim to enter upon the surface of a claim owned or possessed by another.

Sec. 2323. Where a tunnel is run for the development of a vein or lode, or for the discovery of mines, the owners of such tunnel shall have the right of possession of all veins or lodes within three thousand feet from the face of such tunnel on the line thereof, not previously known to exist, discovered in such tunnel, to the same extent as if discovered from the surface; and locations on the line of such tunnel of veins or lodes not appearing on the surface, made by other parties after the commencement of the tunnel, and while the same is being prosecuted with reasonable diligence, shall be invalid, but failure to prosecute the work on the tunnel for six months shall be considered as an abandonment of the right to all undiscovered veins on the line of such tunnel.

Sec. 2324. The miners of each mining district may make regulations not in conflict with the laws of the United States, or with the laws of the state or territory in which the district is situated, governing the location, manner of recording, amount of work necessary to hold possession of a mining claim, subject to the following requirements: The location must be distinctly marked on the ground so that its boundaries can be readily traced. All records of mining claims hereafter made shall contain the name or names of the locators, the date of the location, and such a description of the claim or claims located by reference to some natural object or permanent monument as will identify the claim. On each claim located after the tenth day of May, eighteen hundred and seventy-two, and until a patent has been issued therefor, not less than one hundred dollars' worth of labor shall be performed or improvements made during each year. On all claims located prior to the tenth day of May, eighteen hundred and seventy-two, ten dollars' worth of labor shall be performed or improvements made by the tenth day of June, eighteen hundred and seventy-four, and each year thereafter, for each one hundred feet in length along the vein until a patent has been issued therefor; but where such claims are held in common, such expenditure may be made upon any one claim; and upon a failure to comply with these conditions the claim or mine upon which such failure occurred shall be open to relocation in the same manner as if no location of the same had ever been made, provided that the original locators, their heirs, assigns, or legal representatives, have not resumed work upon the claim after failure and before such location. Upon the failure of any one of several co-owners to contribute his proportion of the expenditures required hereby, the co-owners who have performed the labor or made the improvements may, at the expiration of the year, give such delinquent co-owner personal notice in writing or notice by publication in the newspaper published nearest the claim for at least once a week for ninety days, and if at the expiration of ninety days after such notice in writing or by publication such delinquent should fail or refuse to contribute his proportion of the expenditure required by this section his interest in the claim shall become the property of his co-owners who have made the required expenditures.

CALIFORNIA STATUTES GOVERNING LOCATION OF MINING CLAIMS

The federal statutes outline in a general way the methods to be followed in locating claims, but the state statutes, which have grown out of the miners' customs and district rules which in many cases antedated the federal law, go into details about the requirements. The sections of the Public Resources Code of California quoted below give in full detail the requirements for making valid locations in this state.

Public Resources Code, California[3]

Sec. 2301. Contents and Posting of Lode Location Notice

Any person, a citizen of the United States, or who has declared his intention to become a citizen, who discovers a vein or lode of quartz, or other rock in place, bearing gold, silver, cinnabar, lead, tin, copper, or other valuable deposit, may locate a claim upon such vein or lode, by defining the boundaries of the claim, in the manner hereinafter described, and by posting a notice of such location, at the point of discovery. The notice shall contain:

(a) The name of the lode or claim.

(b) The name of the locator or locators.

(c) The number of linear feet claimed in length along the course of the vein, each way from the point of discovery, with the width on each side of the center of the claim, and the general course of the vein or lode, as near as may be.

(d) The date of location.

(e) Such a description of the claim by reference to some natural object, or permanent monument, as will identify the claim located.

(The first paragraph is a rather loosely worded and incomplete repetition of Sections 2319 and 2320 of the Revised Statutes of the United States, quoted above. The balance specifically sets forth the five essential items needed to make a valid location notice, and should be carefully followed.)

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[3] Parts in italics and within parentheses are reviser's comment, not part of law.

Sec. 2302. Defining Boundaries, Marking Corners

The locator or locators of any lode mining claim shall define the boundaries of the claim so that they may be readily traced, but in no case shall the claim extend more than 1,500 feet along the course of the vein or lode, nor more than 300 feet on either side thereof as measured from the center line of the vein at the surface. Within 60 days after the date of location of any lode mining claim hereafter located, the locator or locators shall erect at each corner of the claim and at the center of each end line, or the nearest accessible points thereto, a post not less than four inches in diameter, or a stone monument at least 18 inches high.

Sec. 2303. Manner of Locating, Marking or Describing Placer Mining Claims

The location of a placer claim shall be made in the following manner:

(a) By posting thereon, upon a tree, rock in place, stone, post, or monument, a notice of location, containing the name of the claim, name of the locator or locators, date of location, number of feet or acreage claimed, and such a description of the claim by reference to some natural object or permanent monument as will identify the claim located.

(b) By marking the boundaries so that they may be readily traced.

Where the United States survey has been extended over the land embraced in the location, however, the claim may be taken by legal subdivisions and no other reference than those of such survey shall be required, and the boundaries of a claim so located and described need not be staked or monumented. The description by legal subdivisions shall be deemed the equivalent of marking.

(This section supplies details which are lacking in the federal statutes for this type of location. It does not, however, specify an exact way of marking a placer claim, as is done for quartz claims. When possible, placer claims should be located by legal subdivisions, as the land office will in practically every case require such conformity with public survey lines before issuing patent. Expense and delay will be saved by locating in this way.)

Sec. 2304. Discovery Work on Mining Claims

(a) Within 90 days after the date of location of any lode mining or placer claim hereafter located, the locator or locators thereof shall sink a discovery shaft upon the claim to a depth of at least 10 feet from the lowest part of the rim of the shaft at the surface, or shall drive a tunnel, adit, or open cut upon the claim to at least 10 feet below the surface.

(b) In lieu of the discovery work required by paragraph (a) of this section, the locator of a placer mining claim may, within 90 days of the date of location, excavate an open cut upon the claim, removing from the cut not less than seven cubic yards of material.

(This provision was intended to curb a heretofore prevalent abuse of the liberal federal statute which allowed holding a mining claim for a maximum period of nearly two years without doing any work. The original requirement as made effective in September 1935, called for enough work to expose the deposit upon which discovery and location was based. In the case of placer locations on buried ancient channels so common in California, it would usually be impossible for the average locator to do this within 90 days. The statute was accordingly amended to the present form in 1939.)

Sec. 2305. Discovery Work on Association Placer Claims

Within 90 days after the date of location of any placer mining claim hereafter located containing more than 20 acres, the locator or locators thereof shall perform at least one dollar's ($1) worth of work for each acre included in the claim. This work may all be done at one place on the claim if so desired, and shall be actual mining development work exclusive of cabins, buildings, or other surface structures. Nothing in this section shall be construed as a modification of the requirements of Section 2304 of this code.

Sec. 2306. Relocations—Discovery Work on Same

The relocation of any lode or placer mining location which is subject to relocation shall be made as an original location is required to be made, except that the relocator may either sink a new shaft upon the ground relocated to the depth of at least 10 feet from the lowest part of the rim of the shaft at the surface, or drive a new tunnel, adit, or open cut upon the ground to at least 10 feet below the surface; or the relocator may sink the original discovery shaft 10 feet deeper than it is at the time of relocation, or drive the original tunnel, adit, or open cut upon the claim 10 feet further or, in the case of placer mining claims, relocator may either excavate a new open cut upon the claim, removing from the cut not less than seven cubic yards of material, or remove from the original open cut not less than seven additional cubic yards of material.

Sec. 2306.5. Perfecting Certain Placer Claim Locations

(This provision allowed a period of 90 days, beginning September 19, 1939, to complete discovery work as required in the amended law Sec. 2304 (b) on those placer claims where literal compliance with the previous requirement had not been feasible.)

Sec. 2307. Penalty for Non-Compliance with Code

The failure or neglect of the locator or locators to comply with the requirements of Sections 2301, 2302, 2304, 2305 or 2306 of this code shall render the location null and void (and no portion of the area within the location shall be subject to relocation by the same locator or locators within the period of three years from the date of the void location).[3]

(The penalty imposed hereunder should not be confused with that resulting from the failure to perform annual assessment work, as covered in Sec. 2321. Under Sec. 2307, the failure to comply with any of the provisions of the state code may result in the claim becoming open to relocation by others in 90 days or less after the date of original location.)

Sec. 2308. Location of Tunnel Right

The locator of a tunnel right or location, shall locate his tunnel right or location by posting a notice of location at the face or point of commencement of the tunnel, which notice shall contain:

(a) The name of the locator or locators.

(b) The date of the location.

(c) The proposed course or direction of the tunnel.

(d) Such a description of the tunnel by reference to some natural object or permanent monument as will identify the claim or tunnel right.

(This section gives the modus operandi for exercising the right given in Section 2323, Revised Statutes of the United States. Refer also to the suggested location form herein.)

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[3] See *Judson* v. *Herrington*, 71 A.C.A. 759, which declares the 3-year prohibition to be in conflict with the federal law. Reprinted in California Div. Mines Rept. 42, pp. 57-60, 1946.

Sec. 2309. Marking Boundary Lines of Tunnel Location

The boundary lines of the tunnel shall be established by stakes or monuments placed along the lines at an interval of not more than 600 feet from the face or point of commencement of the tunnel to the terminus of 3,000 feet therefrom.

Sec. 2310. Amended Location Notice

If at any time the locator of any mining claim, or his assigns, apprehends that his original location notice was defective, erroneous, or that the requirements of the law had not been complied with before filing, or in case the original notice was made prior to the passage of this chapter, and he is desirous of securing the benefit of this chapter, such locator, or his assigns, may file an amended notice, subject to the provisions of this chapter, if such amended location notice does not interfere with the existing rights of others at the time of posting and filing the amended location notice. No amended location notice or the record thereof shall preclude the claimant or claimants from proving any such title as he or they may have held under previous locations.

Sec. 2311. Survey Notes and Certificate Part of Record

Where a locator, or his assigns, has the boundaries and corners of his claim established by a United States deputy mineral surveyor, or a licensed surveyor of this state, and his claim connected with the corner of the public or minor surveys of an established initial point, and incorporates into the record of the claim the field notes of such survey, and attaches to and files with such location notice a certificate of the surveyor setting forth (a) that the survey was actually made by him, giving the date thereof, (b) the name of the claim surveyed and the location thereof, and (c) that the description incorporated in the declaratory statement is sufficient to identify the claim, such survey and certificate becomes a part of the record, and such record is prima facie evidence of the facts therein contained.

Sec. 2312. Mill Site Locations

The proprietor of a vein or lode claim or mine, or the owner of a quartz mill or reduction works, or any person qualified by the laws of the United States may locate not more than five acres of nonmineral land as a mill site. The location shall be made in the same manner as required for locating placer claims.

(See also suggested form for location included herewith.)

(A mill site usually adjoins the exterior lines of a lode claim which it serves, but need not necessarily do so, so long as it is used in good faith for mining or milling purposes in connection with the operation of a lode or quartz mine; but if for mining purposes, these must be auxiliary to, and not actually the extraction of, mineral.)

Sec. 2313. Recording Copy of Location Notice

Within 90 days after the posting of his notice of location upon a lode mining claim, placer claim, tunnel right or location, or mill site claim or location, the locator shall record a true copy of the notice together with a statement of the markings of the boundaries as required in this chapter, and of the performance of the required discovery work, in the office of the county recorder of the county in which such claim is situated. The county recorder shall receive a fee of one dollar ($1) for this service.

(There are now available printed location notice forms which include the form of notice showing performance of discovery work, and these are convenient. If not available, the forms given herein may be copied and attached to the location notice before having it recorded.)

Sec. 2314. Annual Work Required

The amount of work done or improvements made during each year to hold possession of a mining claim shall be that prescribed by the laws of the United States, to wit: One hundred dollars ($100) annually.

Sec. 2315. Affidavit of Annual Labor

Whenever a mine owner has performed the labor and made the improvements required by law upon any mining claim, the person in whose behalf such labor was performed or improvements made, or some one in his behalf shall, within 30 days after the time limited for performing such labor or making such improvements, make and have recorded by the county recorder, in books kept for that purpose, in the county in which the mining claim is situated, an affidavit setting forth the value of labor or improvements, the name of the claim, and the name of the owner or claimant of the claim at whose expense the labor was performed or the improvements were made. The affidavit, or a copy thereof, duly certified by the county recorder, shall be *prima facie* evidence of the performance of such labor or the making of such improvements, or both.

(When work is required, the time for filing the above affidavit expires at the end of 30 days after noon of July 1.)

Sec. 2316. Recorder's Fee for Recording Affidavit

For recording the affidavit required under Section 2315, the county recorder shall receive a fee of ten cents ($0.10) per folio, one dollar ($1.00) for endorsement, and ten cents ($0.10) for indexing the name of each claim and each owner. (Amended 1949.)

Sec. 2321. Effect of Failure to Perform Required Work: Suspension of Right of Relocation

The failure or neglect of any locator of a mining claim to perform development work of the character, in the manner, and within the time required by the laws of the United States shall disqualify such locator from relocating the ground embraced in the original location or mining claim or any part thereof under the mining laws, within three years after the date of his original location, and any attempted relocation thereof by any of the original locators shall render such location void. (Enacted 1939.)[4]

Sec. 2322. Admissibility in Evidence of Location Records: Force and Effect

The record of any location of a mining claim, mill site, or tunnel right in the office of the county recorder, as provided in this chapter, shall be received in evidence and have the same force and effect in the courts of the State as the original notice. (Enacted 1939.)

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[4] See *Judson* v. *Herrington*, 71 A.C.A. 759, which declares the 3-year prohibition to be in conflict with the federal law.

Sec. 2323. Rules Governing Admission of Copies of Records

Copies of the records of all instruments required to be recorded by this chapter, duly certified by the recorder in whose custody such records are, may be read in evidence under the same circumstances and rules as are provided by law for using copies of instruments relating to real estate, duly executed or acknowledged or proved and recorded. (Enacted 1939.)

Sec. 2324. Construction of Chapter Provisions

The provisions of this chapter shall not in any manner be construed as affecting or abolishing any mining district or the rules and regulations thereof within the State. (Enacted 1939.)

DISCOVERY

"The term 'discovery' has a technical meaning in mining. It may be defined as knowledge of the presence of the precious metals [or other valuable mineral [5]] within the lines of the location or in such proximity thereto as to justify a reasonable belief in their existence." [6]

The discovery should be actual, but not necessarily of present commercial value; be situate within free territory and within the boundaries of the location, and may be upon or underneath the surface of the ground. The discovery is sufficient if it justifies a person of ordinary prudence in making expenditure of labor and money with reasonable prospect of success in developing a paying mine.

A lode location must be based on a discovery of rock in place bearing mineral, not necessarily in a fissure, nor with well-defined walls, but the location must include the top or apex of a vein or lode.

Only one discovery of a mineral deposit is required within a placer location, whether it be for 20 acres or an association placer of 160 acres.

A discovery can not be bisected by a side or end line to constitute discovery in two independent locations.

No location is complete until a valid discovery has been made.

LOCATORS

A location may be made without regard to the age, sex, residence, or citizenship of the locator. A corporation may locate to the same extent as an individual. There is no limit to the number of independent lode or placer locations which may be made by either a natural or artificial person, but each location must be based upon discovery therein. A dummy locator is one who joins in the location of an association placer mining claim in the interest of another person or of a corporation for the purpose of permitting such person or corporation to acquire more land than is allowed him or it by law. Such a location contemplates a fraud upon the government and is good only, say, as to 20 acres, but such a location can possibly only be attacked where the government is either actually or constructively a party as in an adverse suit.

Association locators not implicated in such fraud may select and hold their proportionate share of the location—that is, 20 acres each. An association placer mining location is not invalidated by an agreement made after the location and discovery of mineral, giving one person or a corporation an interest in excess of 20 acres.

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[5] Words in brackets added by reviser.

[6] A. H. Ricketts, American mining law: California Div. Mines Bull. 123, p. 346, 1943.

The right to locate a mill site is limited to the proprietor of a noncontiguous vein or lode claim, or the owner of a quartz mill or reduction works, not owning a mine in connection therewith.

A location made by an alien is not void but is voidable.

Colocators are tenants in common; they are not mining partners unless they unite in working the claim.

Subsequent locators, having knowledge of the previous location, can not avail themselves of defects in the prior and subsisting location.

BOUNDARIES

The location must be distinctly marked upon the ground so that its boundaries can be readily traced. These marks may be placed upon or off the claim or be put upon adjoining patented or unpatented ground but with no right to the ground within the overlap. The boundaries of unpatented claims may be shifted or the location floated, provided, the rights of others are not affected thereby.

The federal law (see Sec. 2324 Revised Statutes of U. S. cited above) is silent as to the kind or position of boundary marks, but these details are supplied in part by the state statute (Chap. 4, Secs. 2302, 2303, Public Resources Code, cited above). For lode claims, there shall be erected ''at each corner of the claim and at the center of each end-line, or the nearest accessible points thereto, a post not less than 4 inches in diameter or a stone monument at least 18 inches high.''

The state law is no more specific than the federal regarding the marking of the boundaries of a placer claim not located by legal subdivisions, beyond saying they shall be marked so that they may be readily traced. This law exempts the locator from the necessity of marking the boundaries of placer claims which have been located and described by legal subdivisions. Prudence will dictate care however, in taking advantage of this, as there is often great difficulty in actually finding and proving the identity of old section corners and quarter-section corners.

TYING THE CLAIM

It is essential that the posted notice and the record of the location contain a description of the claim located by reference to some natural object or permanent monument as will identify the claim. Speaking generally, any object or monument that will serve to identify the location will be sufficient, but the locator should select the most prominent object or monument possible under the circumstances. Stakes driven into the ground are the most certain means of identification of mining claims when there are no permanent monuments or natural objects other than rocks or neighboring hills. The reference to such monuments or objects required by the mining law applies only when such reference can be made.

The reference made by the locator to the tie line is not, and is not intended to be, as accurate and correct as if made by a competent surveyor, but it should identify the location with reasonable certainty.

PLACER LOCATIONS

The maximum size of a placer location is 20 acres for an individual and 160 acres for an association of not less than eight persons, or if the association is composed of a less number, 20 acres for each individual therein.

A placer claim upon surveyed or unsurveyed public land must be located upon the ground in such shape and position as to conform as nearly as reasonably practicable to the lines of the public survey.

This means that if the location is laid upon unsurveyed lands such location, if reasonably practicable, should have east-and-west and north-and-south bounding lines, should be rectangular, if practicable, and in compact form.

When the placer deposit lies within a canyon, gulch, or an unnavigable stream, the placer location may exclude land not useful for mining purposes if conformity of location with subdivisional lines is unreasonable.

Because of the recent (1935 and 1939) state legislation affecting placer locations, it now is necessary that certain additional location acts be performed. (See California Statutes cited above.)

Tailings deposited upon public land initiate no right to dump thereon; but such land may be located as a placer mining claim by the producer or another or by the producer as a mill site, for dumping purposes, or it may be "scripped." If the tailings are allowed to flow upon the land of another, he is entitled to them. If the tailings are deposited so as to injure the land of another, without his consent, the latter may recover damages or injunctive relief may be granted.

The smallest legal subdivision recognized and provided for by the federal mining law is 10 acres, which must be square in form.

Within 90 days after the posting of the notice of location, a true copy thereof should be recorded in the office of the local county recorder.

Form of Placer Location Notice (on Surveyed Land)

Notice is hereby given that the undersigned has this ______ day of ______, 19__, located a placer mining claim situate on public surveyed land in ______ Mining District, County of ______, State of California, described as follows: The ______ of section ______, in township ______, range ______, M. D. M., containing ______ acres.

This claim shall be known as the ______ placer mining claim.

______, Locator.

Note: ***(No witnesses required.)***

Form of Placer Location Notice (on Unsurveyed Land)

Notice is hereby given that I, ______, have this ______ day of ______, 19__, located on public unsurveyed lands in the ______ Mining District, County of ______, State of California, a placer claim described as follows: Beginning at a (tree, rock in place, stone, post or monument) upon which is posted the notice of location, running thence (north) six hundred and sixty feet to a post marked ______, thence (east) thirteen hundred and twenty feet to a post marked ______, thence (south) six hundred and sixty feet to a post marked ______, thence (west) thirteen hundred and twenty feet to place of beginning; containing twenty acres.

All of said posts are at least four inches in diameter and set at least one foot in the ground and surrounded by a mound of stone.

This location is situated about (feet) distant from (name some natural object or permanent monument).

The name of this claim is ______.

______, Locator.

Note: ***(No witnesses required.)***

In some cases, printed location notice forms may be purchased which carry the necessary form to be filled out, showing the performance of discovery work required under state law, (Secs. 2304, 2305, cited above).

If these are not available, the following form may be used and attached to the location notice before it is recorded.

To be attached to *PLACER* LOCATION NOTICE when recorded:

NOTICE IS HEREBY GIVEN by the undersigned Locator__ of the within described Placer Mining Claim, in accordance with the provisions of Chapter 644 of the Statutes of 1941, which amends Section 2313 of the Public Resources Code of the State of California relating to mining claims:

That there has been sunk a discovery shaft upon said claim at least ten (10) feet deep measured from the lowest point of the rim ____________ ; a tunnel ____________ ;
(Yes or No) (Yes or No)
adit ____________ upon said claim to at least ten (10) feet below the surface, or an
(Yes or No)
open cut ____________ from which cut there has been removed not less than seven (7)
(Yes or No)
cubic yards of material.

That the discovery work indicated above has been completed within ninety (90) days from the date of location of said claim.

Dated ________________________ 19____. Locator ________________________
____
____

Note: Mark one of the above to indicate how discovery work was done. This may be NEW work or extension of OLD shaft, adit, tunnel or open cut.
A location of either Lode or Placer mining claim is null and void unless such DISCOVERY work is duly performed and a true copy of Location Notice recorded within ninety (90) days from date of location.
Annual ASSESSMENT work must also be performed within one year after the following first day of July from date of location.

The above form of statement has been suggested as meeting the requirements of Chapter 644 of the Statutes of 1941 which amends Section 2313 of the Public Resources Code, relative to the recording of mining location notices.

LODE LOCATIONS

Theoretically, a lode location should be in the form of a parallelogram, having side lines 1500 feet along the course or strike of the vein or lode running 300 feet on each side of the middle of the vein or lode at the surface, and with parallel end lines. But a lode location of less size and of different or any shape is valid; for instance, it may be in the form of a horseshoe or of an isosceles triangle; but such locations carry no extralateral rights. The side lines need not be equidistant from the middle of the vein at the surface and the end lines need not be straight nor of equal length; but its end lines must be parallel with each other or the location carries no extralateral right. If the side lines be across, instead of along the vein, they become the end lines and the location end lines become the side lines of the location as laid upon the ground; and the extralateral right is diminished accordingly. The presumption is that a lode extends to the entire length of the location, but nonmineral land within a placer location may be eliminated by the land department. A valid lode location includes the exclusive right of possession and enjoyment of the surface within its lines and of all veins or lodes having a top or apex within its lines. A location upon the dip of a vein or lode is invalid.

To make the location valid there must be a strict compliance with the local law providing for the manner of locating lode claims, including the new statutory requirement covering discovery work and marking of boundaries. (See Secs. 2301, 2302, 2304, 2306, 2307 Public Resources Code of California.)

FORM OF LODE LOCATION NOTICE

Notice is hereby given that I, ------, do hereby locate and claim (*fifteen*) hundred linear feet of this vein or lode, together with surface ground extending (*three*) hundred feet in width on each side of the middle of said vein or lode and described as follows: Commencing at a post (*or stone monument*) where this notice is posted, which post (*or stone monument*) is at the point of discovery on said vein or lode and on the center line of this location, I hereby claim (*six*) hundred feet extending in a (*southwesterly*) direction along the course of said vein and (*nine*) hundred feet in a (*northeasterly*) direction. The general course of the vein or lode is (*northeasterly*) and (*southwesterly*) as near as can be determined from present developments. The discovery post (*or stone monument*) is situated about ------------ feet from (*name some natural object or permanent monument and give direction*).

The name of this claim is ------ and it is situated in ------ Mining District, County of ------, State of California.

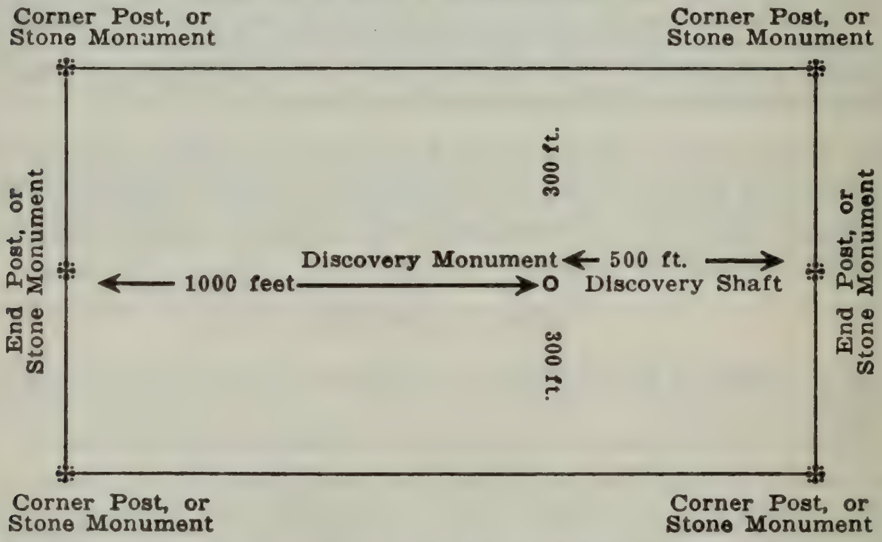
------, Locator.

Date ------------.

Note: (*No witnesses required.*)

(*The post must be not less than four inches in diameter and the stone monument must be at least eighteen inches high.*)

This diagram is intended to give a general ideal plan of location.


Corner Post, or Stone Monument
Corner Post, or Stone Monument
300 ft.
End Post, or Stone Monument
Discovery Monument
500 ft.
1000 feet
Discovery Shaft
End Post, or Stone Monument
300 ft.
Corner Post, or Stone Monument
Corner Post, or Stone Monument

The state law now requires that the location notice shall contain a statement that the boundaries have been marked and discovery work has been done as specified in the statute.

The following form is suggested and may be filled out and attached to the location notice unless printed location blanks provide for these statements.

NOTICE IS HEREBY GIVEN by the undersigned Locator__ of the within described Lode Mining Claim, in accordance with the provisions of Chapter 644 of the Statutes of 1941 which amends Section 2313 of the Public Resources Code of the State of California relating to mining claims, that there has been erected at the discovery point, at each corner and at the center of each end line of the said claim, a post not less than four (4) inches in diameter or a stone monument, at least eighteen (18) inches high.

That there has been sunk a discovery shaft upon said claim at least ten (10) feet deep measured from the lowest point of the rim ------------ ; a tunnel ------------ ;
(Yes or No) (Yes or No)

adit ------------ ; open cut ------------ ; upon said claim to at least ten (10) feet
(Yes or No) (Yes or No)
below the surface.

That the discovery work indicated above has been completed within ninety (90) days from the date of location of said claim.

Dated ------------------------, 19----. Locator ------------------------
----

Note: Mark one of the above to indicate how discovery work was done. This may be NEW work or extension of OLD shaft, adit, tunnel or open cut.
A location of either Lode or Placer mining claim is null and void unless such DISCOVERY work is duly performed and a true copy of Location Notice recorded within ninety (90) days from date of location.
Annual ASSESSMENT work must also be performed within one year after the following first day of July from date of location.

TUNNEL-SITE LOCATIONS

In California the state law prescribes the manner of locating a tunnel site.

A discovery of mineral is not essential to create a tunnel right nor to maintain possession thereof. A failure to work the tunnel site for 6 months is considered an abandonment of the right to all undiscovered veins on the line of the tunnel. The line of the tunnel is the width thereof. The tunnel site must be located upon unappropriated public land and by diligently prosecuting work thereon its claimant has the right of possession of all veins or lodes within 3000 feet from its face on the line thereof, not previously known to exist, discovered in such tunnel, the same as if discovered from the surface. When the discovery is made the tunnel site owner is called upon to make a location on the surface of the ground containing the vein and thus create a mining claim. Such vein may be located 1500 feet on either side of the tunnel or in such proportion thereof on either side as may be desired. The right to such vein dates by relation back to the time of the location of the tunnel. Surface mining claims located by another person subsequent to the commencement of the construction of the tunnel are taken and held subject to any rights of the tunnel owner thereafter developed. The tunnel site may be utilized for development purposes and the work may be credited as assessment work upon claims which are in fact benefited by it. A tunnel site can not be patented.

FORM OF TUNNEL SITE LOCATION NOTICE

Notice is hereby given that I, ------, have this ------ day of ------, 19--, located a tunnel site to be known as the ------ tunnel claim, situate in ------ Mining District, County of ------, State of California, and described as follows: Commencing at this notice of location which is posted at the face or point of commencement of this tunnel and situate about ------ feet from a (*blazed tree*) ------ inches in diameter, marked ------ (*or some other natural object or permanent monument*). The boundary lines of said tunnel site are marked by (*stakes or monuments*) placed along said lines at an interval of not more than six hundred feet from the face or point of commencement of the tunnel to the terminus of three thousand feet therefrom.

------, Locator.

Note: (*No witnesses required.*)

MILL-SITE LOCATIONS

The proprietor of a vein or lode claim or the owner of a quartz mill or reduction works may locate not more than 5 acres of non-mineral land not adjacent to a lode as a mill site in the same manner as the state law provides for the locating of placer claims. There is no certain form required for a mill site, but it may be noted here that 726 feet by 300 feet contains 5 acres.

A separate mill site is not, necessarily, complemental to each lode location. If the lode location is forfeited or abandoned, the right to the mill site is lost. There is no specific time within which a mill site shall commence to be used as such but the land must be used in good faith in connection with the ostensible purpose for which it was located. It may be located for dumping purposes. It may be located within a forest reserve but not within the limits of a railroad grant. Subsequent mineral discovery within the mill site does not affect the title thereto.

No annual expenditure is necessary on a mill site nor is any statutory expenditure required thereon when patent is applied for in conjunction with a lode claim, as the expenditure on such claim is sufficient.

Form of Mill Site Location Notice

Notice is hereby given that I, ______, proprietor of that certain vein or lode claim known as the ______ mining claim (*or the owner of that certain quartz mill or reduction works known as the* ________) have this ______ day of ________, 19__, located five acres of nonmineral land to be known as the ______ mill site, situate in ______ Mining District, County of ______, State of California, and described as follows: Commencing at a point from which (*name natural object or permanent monument*) bears ______, feet; thence (*south*) seven hundred and twenty-six feet; thence (*west*) three hundred feet; thence (*north*) seven hundred and twenty-six feet; thence (*east*) three hundred feet to the point of beginning.

The name of this mill site is ______.

______, Locator.

Note: (*No witnesses required.*)

TOWNSITES

No title can be acquired under a townsite entry to any vein of gold, silver, cinnabar, copper, or lead, nor to any valid mining claim or possession, held under existing laws.

A valid mining claim, therefore, is not affected where it was known prior to the townsite patent that a mineral vein existed where the discovery was made; that is, land held as a valid and subsisting mining claim at the time of the issuance of the townsite patent, does not pass under such patent, nor is the title or right of possession of the location at all affected thereby.

Mineral land within a patented townsite can not be located.

There is no conflict between a lode or a placer patent and a townsite patent, and there can be none.

A mill site has been held to be a mining claim within the purview of the townsite act.

RELOCATION

A subsequent location of a forfeited or abandoned mining claim is a relocation and not an original nor amended location. It is made in the same manner and is subject to the same conditions as an original location. It is void if it embraces a valid and subsisting claim. A valid relocation on the ground of forfeiture due to failure to perform annual labor can not be made until after the expiration of the assessment year; i.e., after 12 o'clock noon on July 1; but if forfeiture is due to failure to observe state law, relocation may come after 90 days but an abandonment of the claim gives the right of immediate relocation. All improvements which are attached to or become a part of the realty pass to the relocator. The location rights, however, may be preserved by a resumption of labor in the absence of an intervening right. There can be no provisional relocations; that is to say, the validity of the relocation can not be made to depend on whether or not the mine owner failed to do the annual work subsequently or may abandon his claim. A mining claim is not subject to relocation for failure to perform the assessment work if such work has been resumed after the expiration of the year and before any valid relocation is attempted. A person, holding confidential relations with the owner of a mining claim, for example, a lessee or optionee, who in violation of a contract or in breach of the trust attempts to relocate the claim in his own name, will be held as a trustee for the rightful owner and he will secure no advantage by such act. A relocation by a cotenant inures to the benefit of his cotenants and he can not by recording in his own name prejudice their rights nor forfeit his own undivided interest thereby. A relocator or other person may attack the verity of the recorded affidavit of labor and show its falsity. (See Sec. 2306, Public Resources Code of California.)

AMENDMENT OF LOCATION OR RECORD

The office of an amended location is to cure defects or supply omissions in the original location or in the posted notice or the record. It may serve to change the boundaries or the name of the claim or add the names of additional locators. It may include additional territory if without prejudice to the rights of others. It does not require additional discovery in the added ground, physical possession nor additional expenditure. It works no forfeiture of previously acquired rights not inconsistent with the amendment. It relates back to the date of the original notice where no adverse rights have intervened. It must be based upon a preexisting but not necessarily perfect location. It can not be made to exclude the name of a colocator without his knowledge and consent. It can not be made by a person who has parted with his title. There is no limit as to the time within which it may be posted or recorded.

Form of Amended Location Notice

Know all men by these presents, that ______, the undersigned, has this ______ day of ______, 19__, amended, located, and claimed and by these presents does amend, locate, and claim by right of discovery and amended location in compliance with section 2310 of the Public Resources Code of California (*fifteen*) hundred linear feet of the ______ lode, vein, ledge, or deposit along the vein together with (*three*) hundred feet on each side of the middle of the said vein at the surface situate in ______ Mining District, County of ______, State of California, and described as follows: Beginning at corner No. 1, whence (*name some natural object or permanent monument*) is distant ______ feet in a ______ direction, thence (*northeasterly*) (*fifteen*) hundred feet to corner No. 2, thence (*southeasterly*) (*three*) hundred feet to end center monument, thence (*southeasterly*) (*three*) hundred feet to corner No. 3, thence (*southwesterly*) (*fifteen*) hundred feet to corner No. 4, thence (*northwesterly*) (*three*) hundred feet to end center monument, thence (*northwesterly*) (*three*) hundred feet to point of beginning. This being the same lode originally located on the ______ day of ______, ____, and recorded on the ______ day of ______, ______, in Book ______, page ______ of ______ records in the office of county recorder of said ______ County. This further and amended notice of location is made without waiver of any previously acquired rights, but for the purpose of correcting any errors or defects or omissions in the original location, description, or record and to secure all the benefits of said section of said Civil Code.

______, Locator.

The statement about discovery work and marking of lode claims should be used.

ANNUAL EXPENDITURE OR ASSESSMENT WORK

Annual expenditure consists of labor done or improvements made upon both lode and placer claims and must be *worth* at least one hundred dollars. It must be done or made before 12 o'clock noon of the first day of July of each year subsequent to the location year until patent or the receiver's final receipt has issued to the mine claimant (unless congress has declared a moratorium for that particular year, which must be consulted as each moratorium may, and usually does, vary in detail or unless the location was made prior to governmental withdrawal or the Leasing Act. Within withdrawn areas neither assessment work nor patent is necessary to preserve the possessary right of the claimant; and he holds his claim in perpetuity unless he loses his rights by abandonment). If not so made, and there is no resumption of labor the claim is subject to adverse relocation.

Assessment work may be done either underground or upon the surface, upon or off the claim itself, if of benefit or value to it. Any work done for the purpose of discovering minerals is ''improvements'' within the spirit of the statute. Any building, machinery, roadway, or other improvement used in connection with, and essential to the practical development of the claim will enter into and form a part of the expenditure for improvements. Under some circumstances the services of a watchman may be counted as annual expenditure. In determining the amount of work done on a claim for the purpose of representation, the test is as to the reasonable value of said work, not what was paid for it nor what the contract price was, but it depends entirely upon whether or not said work was *worth* the sum of one hundred dollars.

Labor may be done or improvements made upon or at a distance from any one of the locations comprising a group of claims when of benefit and value to the entire group. Any location within the group not so benefited may become subject to forfeiture. The expenditure must equal in the aggregate the amount required on all the locations. The test of sufficiency is whether the expenditure tends to facilitate the development or actually promotes or directly tends to promote the extraction of mineral from or improve the property or be necessary for its care or the protection of the mining works thereon or pertaining thereto.

The amount of the annual expenditure upon a placer claim is the same whether for 20 acres or on an association claim of 160 acres; viz., one hundred dollars.

A certain number of days work at a certain sum a day, or work of a certain character or extent do not constitute the requisite expenditure under the mining laws.

Labor done or improvements made may be sufficient to hold the claim although not in fact paid for or when gratuitously performed; but payment for work not done will not suffice.

The annual expenditure may be made by the locator, his heirs, assigns or legal representatives, or by some one in privity therewith, or by one who has an equitable or beneficial interest. A stockholder in a corporation claiming the property, or a receiver appointed by a court are within the rule; but labor done or improvements made by a trespasser or stranger to the title will not inure to the benefit of the claimant.

Annual expenditure is not required upon a mill site nor upon a tunnel site; but failure to prosecute the work on the tunnel for 6 months shall be considered as an abandonment of the right to all undiscovered veins on the line of such tunnel. Yet the work on it may count as annual labor on claims which it is so run as to cut and develop; or be applied as patent expenditure.

Wrongful adverse possession of a mining claim excuses the rightful owner or locator from doing the assessment work required by law, during the time of such adverse possession.

Annual assessment work may be applied to patent expenditure.

FORFEITURE OF INTEREST FOR FAILURE TO PAY SHARE OF TAXES

Chapter 1292, Statutes of 1945, effective September 15, 1945, provides that upon the failure of any co-owner of a mine or claim to contribute his proportionate share of the taxes which have been levied and assessed upon the mine or claim for the period of five years, the co-owner or co-owners who have paid such share may at the expiration of the five years serve upon the delinquent co-owner notice thereof. If the delinquent co-owner fails or refuses to contribute his share of such taxes within 90 days after the service of such notice, the co-owner contributing such share may file in the superior court of the county in which the mine is situated, a petition setting forth the facts. After proper notice and hearing, the court may order judgment vesting the interest of the delinquent in the mine or claim in the petitioner.

WAR-TIME EXEMPTIONS FROM ANNUAL LABOR

Public Law No. 861, passed by the 76th Congress and known as the Soldiers' and Sailors' Civil Relief Act of 1940, provides (Sec. 505) that the terms of Sec. 2324 of the Revised Statutes of the United States, requiring annual labor on mining claims, "shall not apply during the period of his service, or until six months after the termination of such service, or during any period of hospitalization, because of wounds or disability incurred in line of duty, to claims or interests in claims which are owned by a person in military service and which have been regularly located and recorded."

In order to obtain the benefits of this section the claimant of such mining location shall, before the expiration of the assessment year during which he enters military service, file or cause to be filed in the office where the location notice or certificate is recorded, a notice that he has entered such service and that he desires to hold his mining claim under this section.

Sec. 506 of the same law permits the suspension of mining operations on United States land held under permit or lease for a similar period and waives payment of rentals or royalties for such period, provided that the permittee or lessee shall within 6 months after the effective date of the act, or 6 months after his entrance into military service notify the General Land Office by registered mail of his entrance into such service and of his desire to avail himself of this section. The above law was approved in time to affect work for the year ended July 1, 1941.

On May 3, 1943 another act of congress was approved which suspended the requirement for annual assessment work on *all* mining claims in the United States including Alaska until noon July 1 following the cessation of hostilities in the war.

In order to benefit by the act, the claim owner must file or cause to be filed, in the office where the location notice or certificate is recorded, (which in California is the County Recorder's office) on or before 12 o'clock noon July 1 for each year that the act remains in effect, a notice of his desire to hold said claim. Similar acts were in effect for each year until July 1, 1948.

H. R. 1754, which became Public Law 107, Eighty-first Congress, upon being signed by the President on June 17, 1949, provided: "That the provision of section 2324 of the Revised Statutes of the United States, which requires on each mining claim located, and until a patent has been issued therefor, not less than $100 worth of labor to be performed or improvements aggregating such amount to be made each year, be, and the same is hereby, suspended as to all mining claims in the United States until the hour of 12 o'clock meridian of the 1st day of July 1949: Provided, That every claimant of any such mining claim in order to obtain the benefits of this Act shall file, or cause to be filed, in the office where the location notice or certificate is recorded, on or before 12 o'clock meridian of August 1, 1949, a notice of his desire to hold said mining claim under this Act: Provided further, That any labor performed or improvements made on any such mining claim during the year ending July 1, 1949, may be credited against the labor or improvements required to be performed or made for the year ending at 12 o'clock meridian on the 1st day of July 1950.

Sec. 2. Notwithstanding the provisions of any Act of Congress to the contrary, any person who hereafter prospects for, mines, or removes, by strip or open pit mining methods, any minerals from any land included in a stock raising or other homestead entry or patent, and who had been liable under such an existing Act only for damages caused thereby to the crops or improvements of the entryman or patentee, shall also be liable for any damage that may be caused to the value of the land for grazing by such prospecting for, mining, or removal of minerals. Nothing in this section shall be construed to impair any vested right in existence on the effective date of this section."

CONTRIBUTION

Persons who acquire undivided interests in a mining claim by location or otherwise are known as cotenants or co-owners, and any one or more who fail to contribute the proportionate share of the assessment expenditure may be "advertised out" by the remaining party or parties. This may be done by personal service, in writing, or by publication in a newspaper published nearest the claim for at least once a week for 90 days and if at the expiration of 90 days after such notice in writing or 180 days from the first day of such publication such delinquent or delinquents should fail or refuse to contribute his proportion of the expenditure required by law, his interest in the claim shall become the property of his co-owners who have made the required expenditures and given said notice. California law provides for the giving of such notice for contribution and the manner of establishing the same of record in the office of the local county recorder, and also of the fact of payment or nonpayment, as the case may be.

PROOF OF ANNUAL LABOR

California mining law provides for the making, recording and legal effect of affidavits of annual expenditure. Within 30 days after the time limited for performing labor or making improvements upon a mining claim—that is, 12 o'clock noon of July 1—the mine owner or some one in his behalf may make and have recorded by the local county recorder an affidavit setting forth the value of the labor and improvements made, the name of the claim or claims, and the name of the owner or claimant of such claim at whose expense the same was made or performed. If this affidavit is filed before or within the said time, it presents prima facie evidence of the facts properly therein stated; but not otherwise. If filed after said 30 days, it has no legal effect. This affidavit does not prevent other proof by the claimant nor attack by his adversary. Neither the failure to record the affidavit nor a mistake therein will work a forfeiture of the location. Its due filing tends to prevent an adverse relocation.

FORM OF AFFIDAVIT OF ANNUAL LABOR

State of California} ss
County of________}

______, being first duly sworn, deposes and says, that at least (*one*) hundred dollars worth of labor was performed (*or improvements made*) between 12 o'clock noon of the first day of July, 19__, and 12 o'clock noon of the first day of July, 19__, upon the ______ mining claim situate in the ______ Mining District, County of ______, State of California. Such expenditure was made by or at the expense of ______, the owner of said claim, for the purpose of complying with the federal and Californian mining laws pertaining to annual assessment work.

Subscribed and sworn to before me this ______ day of ______, 19__. ______, Notary Public in and for the County of ______, State of California.

My commission expires ______.

RESUMPTION OF LABOR

A mine claimant who has failed to do the annual labor during the statutory assessment year may resume work at any time thereafter, in the absence of an intervening right.

To "resume work" is to begin work in good faith and diligently prosecute the same to completion before a valid adverse relocation, and thereafter the rights of the mine claimant are precisely what they were before the default.

Work is not resumed by the mere purchase of material or the mere bringing of the same upon the claim.

The Federal Leasing Act of 1920 did not have the effect of extinguishing the right of the locator under the mining act to save his claim under the original location by resuming work at any time after failure to perform the annual assessment labor in the absence of adverse relocation or intervening right.

INDEPENDENT CONTRACTOR

Where the mine owner retains the right to direct the mode and manner in which the assessment work shall be done for an agreed per diem, the relation of master and servant exists and the employer is liable in damages for injuries which may be sustained by his employee while he is engaged in such employment. But, if work is done under a contract, such as to excavate a tunnel of certain dimensions for an agreed number of lineal feet, or to sink a shaft of a certain size to a certain depth, for an agreed amount, and the mine owner has no right of control as to the mode of doing the work contracted for, the party so doing such work is an independent contractor, and he, and not the mine owner, is liable for such injuries.

FORM OF CONTRACT

The terms of the agreement made this ______ day of ______, 19__, between ______, party of the first part, and ______, party of the second part, are as follows, viz: That the said party of the second part shall excavate or run ______ lineal feet of tunnel work within the ______ mining claim situate in the ______ Mining District, County of ______ and State of California, commencing at a point to wit: ______ feet (*west*) from the (*east end center monument of said claim*) for the agreed sum or price of ______ dollars per lineal foot; said tunnel to be ______ feet in width and ______ feet in height, in the clear, and to be timbered where necessary. Payment therefor by said party of the first part shall be made in full within ______ days after the full completion of said work. Work upon said tunnel under this contract shall commence within ______ days from the date hereof and the same shall be fully completed in proper and minerlike manner by said party of the second part on or before the thirtieth day of June next thereafter ensuing; said party of the second part to hold said party of the first part harmless as against all and every lien of laborers, miners, and mechanics, and for materials furnished.

In witness whereof the said parties hereto have hereunto, and to its duplicate, set their hands the day and year first above written.

____

____

PATENTS

A patent is not essential to the enjoyment of a mining claim. There is no restriction as to the time when it shall be applied for nor as to its use or sale. It confers no greater mining rights than those obtained by a valid location. It, however, establishes the exterior boundaries of the claim, that discovery has been made, and dispenses with the performance of annual labor. A patent is not always conclusive of the title, as, for one thing, it may, possibly, be shown that the patentee is an undisclosed trustee.

Lode, and placer locations upon unsurveyed lands, must be officially surveyed for patent. No survey is required for placer locations laid in conformity with legal subdivisions.

ADVERSE CLAIMS

When a patent is applied for, the owner of a prior conflicting location must duly institute adverse proceedings; otherwise, he will be treated in law as having voluntarily waived his prior and superior rights, and his adversary will secure a patent covering his location or a part thereof. The adverse must be filed in the local land office within the 60-day publication of the application for patent and followed by suit in a court of competent jurisdiction within 30 days thereafter and be diligently prosecuted to final judgment. No equitable title nor existing lien is disturbed by the issuance of the patent.

PROTESTS

A protest may be filed at any time by any person before patent actually issues. The protest may be directed against the patenting of the claim as applied for upon any ground tending to show that the applicant has failed to comply in any matter essential to a valid entry under the patent proceedings; as for instance, that no mineral has been disclosed within the claim applied for, that the necessary expenditure of five hundred dollars has not been made by the proper party; or it may be filed by a cotenant excluded from the application for patent. A protest never can take the place of an adverse.

TENANCY IN COMMON

A tenancy in common arises from the joint location of or ownership in a mining claim and consists of undivided interests therein. The parties thereto are not mining partners unless they work the mine together by agreement. A cotenant who does not exclude his cotenants, may work the mine in the usual way and extract ore therefrom without being chargeable with waste or liable to the other cotenants for damages, and an injunction will not be granted at their instance to prevent the working of the mine.

The operating cotenant works the property at his own expense; he alone must sustain any loss which results from his working the property and he alone is responsible for the debts thereby contracted; he must account to the nonparticipating cotenants for their pro rata share in the net results.

The title of a cotenant may be divested after due notice, to contribute his proportion of the annual expenditure, or by the actual adverse possession for the statutory period of the other cotenants, or some of them, evidenced by ouster, or by obtaining a patent from the government in their own names unless the excluded cotenant brings suit to enforce the trust when not barred by laches, the statute of limitations or the rights of third parties without notice. Hence, such excluded cotenant need neither file an adverse nor a protest against such application for patent. A cotenant becomes a trustee for his cotenants when he relocates the claim or permits its relocation by a third person with whom he is in collusion, or obtains a patent in his own name.

A cotenant may maintain an action for the recovery of the claim without joining his cotenants. A cotenant may sell or encumber his undivided interest at pleasure but he can not sell, lease, or encumber a specific part of the common land.

See also, *Working the Claim,* below.

MINING PARTNERSHIP

(Chap. 5, Secs. 2351-2360 incl., Public Resources Code of California.)

To constitute a mining partnership, two or more parties must be associated together in the ownership or possession of a mining claim in some way and actually engage in working the same.

The partnership is not dissolved by the death of a partner nor by the sale of a partnership interest. The purchaser, from the date of his purchase, becomes a member of the partnership. The partners are in the relation of trustees for each other. The property worked and the business of the partnership may be controlled by a majority of the members of the partnership acting for the best interest of all concerned. Each partner is jointly liable for the debts of the firm.

As previously suggested, the property worked is not necessarily property owned by the partnership, if it be so, it is subject to the lien of each member of the firm for debt due to himself or to the creditors of the firm. One mining partner may sue his copartner for an accounting. A partner may properly sell his interest at a greater price than that received by the other partners.

GRUBSTAKE CONTRACTS

(Chap. 7, Sec. 2606, Public Resources Code of California.)

A grubstake contract is an agreement, in writing, and recorded in the office of the county recorder of the county in which said instrument is made. It must be duly acknowledged before a notary public or other person competent to take acknowledgment. It is prima facie evidence in all courts of this state in all cases wherein the title to mining locations and other locations under the mining laws of this state are in dispute.

A grubstake, or prospecting contract, as it is sometimes called, is where one of the parties thereto, called the outfitter, is to furnish the other, called the prospector, supplies, money or both, to and while the other is prospecting for and obtaining mineral land, by location, for their joint advantage or in such proportion as may be agreed upon. It is the duty of the prospector to use reasonable diligence and make reasonable exertions in seeking mineral deposits, and within a reasonable time make proper location covering discovery. It does not constitute a mining partnership unless the parties thereto actually engage in the joint working of the property; otherwise, they are tenants in common.

All locations made during the existence of the contract inure to the benefit of each of the parties thereto, whether made in the name of only one of them, or in the name of a third person, at the instigation of either. Where a prospector conceals locations made in his own name, or for him, individually, he holds the title thus acquired, or the property for which it is exchanged or the price for which it is sold as a trustee in bad faith for the use and benefit of the outfitter, and will be compelled to make restitution.

It is essential to a right in mining property acquired under a grubstake contract that such property should be acquired by means of the grubstake furnished and pursuant to such contract.

The contract must be founded upon an adequate consideration, and be just and reasonable; that is, it must not be a hard bargain on the prospector.

OPTION

An option is a right acquired by contract to accept or reject a present offer within a limited time. It may be coupled with a lease. Time is of the essence of the contract, whether so therein expressed or not. It must be based upon a sufficient consideration; otherwise, it may be withdrawn at any time before acceptance. A consideration of one dollar, in the absence of fraud or bad faith, or the making of expenditures upon the property, as for instance, the performance of the annual assessment work thereon, is a sufficient consideration. After acceptance by the optionee, the parties are mutually bound and the option may be specifically enforced. An option usually is accompanied by the duly executed deed of the optioner, which is placed in escrow to be delivered to the optionee upon his performance of the conditions of the option, or to be returned to the maker in the event of default; in the meantime the title to the property remains in the grantor and subject to claims against him. The deed when delivered will relate back to the date of the escrow agreement and cut off any intervening rights or equities acquired by a third party who had notice of the terms and conditions of the escrow. Hence, the option should be recorded by its holder. At the time the escrow is made, and as a part thereof the option holder properly should execute a quitclaim of the property to the optioner to be delivered to him upon default of the optionee or to the latter upon full compliance with the terms of the option. This is to clear the record title to the property, if there be no conveyance under the terms of the option.

Delivery of the deed by the escrow holder, contrary to instruction, confers no title, particularly as against those who take with notice.

Short Form of Option

In consideration of the sum of ______ dollars, to me in hand paid, I, the undersigned, will sell to ______ my certain mining claim known as ______ situate in ______ Mining District, County of ______ and State of ______ for the sum of ______ dollars, at any time within ______ months from date, payable as follows, to wit: ______.

Upon full payment made I will convey said mining claim to said optionee by a good and sufficient deed.

The right of entry and possession of said premises is hereby given to said optionee together with the right to extract ore therefrom, but with no right thereto or removal thereof, unless and until this option be consummated according to its terms.

All work done upon said mining claim by said optionee shall be done in a minerlike manner and at the sole cost and expense of the optionee. Actual work upon said premises to commence on ______ and to proceed with reasonable diligence unless prevented by strikes, the elements, unavoidable accidents or other causes beyond the control of the optionee.

The optionee shall keep said premises free and clear of all costs, liens and encumbrances done, made or suffered by him—and see that the notice of non-responsibility which may be posted by the optioner upon said premises to protect the same from such liens, is kept in place.

The optionee hereby agrees to carry workmen's compensation insurance in a responsible company, said policy to be placed in force immediately upon the commencement of said work.

The optionee shall and will quietly and peaceably quit and surrender said premises and any ore extracted by him therefrom upon the termination of this option from any legal cause.

Upon the failure to make any payments herein provided for upon said purchase price of said premises at the time herein specified for the same to be made, the right of the optionee shall immediately cease and determine and the payments theretofore made by him shall immediately become the property of the optioner, and the optionee hereby waives all claim thereto.

All machinery and improvements placed upon said premises by the optionee may be removed by him within ______ days after the termination of this option.

Witness my hand this ______ day of ______.

____

LEASES

Each mining lease has its own peculiar details. The form of words used is of no consequence. It is the intention of the parties, as expressed in the instrument, and not its form that determines whether it is a lease or a license or a contract for labor. If the contract gives exclusive possession it is a lease; if it merely confers the privilege of occupation, under the owner, it is a license; if it fixes a rule for compensation for services rendered, as, for instance, a share of the profits realized in working the mine, it is a contract for labor. A lease is sometimes coupled with an option to purchase the property leased, in which case they are separate instruments and the option may outlive the lease. Time is always of the essence of both documents whether so expressly stated or not. Where there is any doubt or uncertainty as to the meaning of covenants in such a lease they are construed strongly against the lessor and in favor of the lessee. A covenant to work the property continuously means continuous to the end of the term. A mere covenant to work the property is not tantamount to a covenant to work continuously. If the payment of royalty is provided for, the lessee is bound to proceed with his mining operations with reasonable diligence. The lease is subject to abandonment or forfeiture. A location may be made and leased on the same day. No lease should be for a longer period than twenty-five years. If it be for a period of one year, or less, it need not be in writing. Where there is no agreement in the lease against subletting, the lessee has the right to sublease all or portions of the land for the purpose specified in the lease. A stipulation as to the removal of machinery or other improvements placed by the lessee is controlling. The term "gross proceeds" means the entire proceeds of the ore mined, less the cost of sampling, freight, and treatment of the ores.

SHORT FORM OF LEASE

This agreement of lease made and entered into this ______ day of ______, 19____, by and between ______ and ______ Witnesseth: That the lessor for and in consideration of ______ dollars, cash in hand paid, receipt of which is hereby acknowledged, and of the covenants and agreements hereinafter contained on the part of the lessee to be paid, kept and performed, does grant, convey, demise, and let exclusively unto the said lessee that certain tract of land situate in ______ Mining District, County of ______, State of California, described as follows:

(*Insert description*)

for the sole purpose of exploring, operating and mining precious and other minerals and to sell the products thereof and to pay to the lessee a royalty of ________ percent of the gross proceeds within ten days after each clean up.

The lessee agrees to keep said premises free and clear of all costs, liens and encumbrances done, made or suffered by permit, the lessor to place and maintain in a conspicuous place upon said premises such notice as shall be lawfully necessary to protect the lessor against such claims.

All machinery and improvements placed upon said premises by the lessee may be removed by him within ______ days after the termination of this lease.

The lessee hereby agrees to carry a workmen's compensation policy in a responsible company; said policy to be placed in force upon the commencement of said work.

It is agreed that this lease shall remain in force for a term of ______ years from this date.

Witness our hands the day and year first above written.

FORM OF NOTICE OF NONRESPONSIBILITY FOR LABOR OR MATERIALS FURNISHED

Notice is hereby given to all persons, that the undersigned ______ is the owner of ______ mine (*or mining claims*) hereinafter described, with all the improvements thereon. That said mine (*or mining claims*) now is in the possession of and is being worked and operated by ______, pursuant to a contract (*or option to purchase, or lease*) made and executed by the undersigned in favor of said ______, dated ______ 19____, said contract (*or option to purchase, or lease*) to be in force up to and including ______ 19____.

The undersigned is not working nor operating said mine (*or mining claims*), nor any portion thereof, and does not intend to work or operate said mine (*or mining claims*), nor any part thereof, nor purchase any supplies or materials therefor, during the life of said contract (*or option to purchase, or lease*) with said _____.

The name of said mine (*or mining claims*) is ______ and is situate, lying and being in ______ Mining District, County of ______, State of California. The notice of location of said mine (*or mining claims*) being duly recorded in Book ______, at page ______, of the records of said ______ county in the office of the county recorder of said county to which said record reference is hereby made for a more particular description of said mine (*or mining claims*).

In witness whereof, the said ______ has hereunto set his hand this ______ day of ______, 19____.

State of California} ss
County of_________}

______, being first duly sworn, according to law, deposes and says: That he is the owner of the premises particularly mentioned and described in the foregoing Notice of Nonresponsibility for Labor or Materials Furnished. That he has read the same and knows the contents thereof. That the same is true of his own knowledge. Subscribed and sworn to before me this ______ day of ______, 19____.

Notary Public in and for the County of ______,
State of California.

My commission expires ______.

Note.—This notice must be posted in a conspicuous place upon the property within ten days after the owner (or person having or claiming interest therein) has obtained knowledge of construction, alteration or repair work or labor upon such property and he should file for record a verified copy of said notice in the office of the proper county recorder. The foregoing verification may be made by any one having knowledge of the facts, on behalf of the owner or person for whose protection the notice is given.

DEEDS

A mining claim can be transferred only by operation of law or by a deed in writing; but a discoverer of mineral may transfer his right of location by parol. A mining claim which has a known descriptive name may be sufficiently described by such name, coupled with a proper reference to the record, or if patented, to the survey number. That a claim is known by several names and only one of them is given in the deed is immaterial. Minerals may be granted without the surface, or vice versa. Where there is a severance, the owner of the mineral has a right to occupy so much of the surface as is reasonably necessary for mining purposes. No attesting witnesses to the execution of a deed are required. If the title to an unpatented claim stands alone in the name of one spouse, it is not essential to the title that the other spouse should join in the execution of the deed.

A quitclaim deed is sufficient to pass the title, if clear.

Form of Deed

I, ______, grant (*or quitclaim*) to ______, that certain mining claim situate in the ______ Mining District, County of ______, State of California, and being the ______ mining claim, and more fully described in volume ______, page ______, of the records of (*quartz claims*) records of said county (*or being Mineral Survey No.* ___).

Witness my hand this (*insert day*) of (*insert month*), 19__.

______.

WORKING THE CLAIM

To work a mining claim is to do something toward making it productive, such as developing or extracting an ore body after it is discovered.

A mine owner is entitled to work his mining claim in a lawful manner; but no manner can be considered lawful which precludes another from the enjoyment of his rights, if his work in fact injures the property of another, be he ever so cautious or careful to avoid injurious consequences. (For instance, allowing his tailings to flow upon another's land without his consent.) In such case, the trespasser not only loses his title to the tailings but is liable for damages besides.

The word ''shift'' means a set of workmen who work in turn with other shifts, as a night shift. It means, also, a day's work.

See also *Tenancy in Common,* above.

PAYMENT OF WAGES

Chapter 628, Article 3, Section 270, Statutes of 1945 (Labor Code) changed slightly the wording of this requirement. It now reads as follows:

> "No person, or agent or officer thereof, engaged in the business of extracting or of extracting and refining or reducing minerals other than petroleum, except persons having a free and unencumbered title to the fee of the property being worked and except mining partnerships in respect to the members of the partnership, shall fail or neglect, before commencing work in any period for which a single payment of wages is made, to have on hand or on deposit with a bank or trust company, in the county where such property is located or if there is no bank or trust company in the county, then in the bank or trust company nearest the property, cash or readily salable securities of a market value sufficient to pay the wages of every person employed on the mining property, or in connection therewith, for such period.
>
> Any person, or agent or officer thereof, who violates this section is guilty of a misdemeanor."

See also *Independent Contractor,* above.

FIXTURES

(Chap. 7, Sec. 2601, Public Resources Code of California.)

A fixture is an article which may or may not actually be affixed to the mine. In this state sluice boxes, flumes, hose, pipes, railway tracks, blacksmith shops, mills, and all other machinery or tools used in working, or developing a mine are deemed to be affixed to the mine. See also *Relocation,* above.

LOCATION WORK AND ASSESSMENT WORK DISTINGUISHED

Confusion of thought has arisen among mining locators as to the effect of the provision of the state mining law relating to location or discovery work upon both lode and placer mining claims as affecting the federal requirement of annual assessment work upon such locations. There is no conflict between the two laws nor is the one merged with the other. Hence, a location of either lode or placer is null and void unless such location work is duly performed; and the possessory right to an unpatented location can not be maintained without due performance of the annual assessment work.

In other words, the state statute places an **additional** burden upon the mining locator, on claims filed on and after September 15, 1935.

USE OF WATER

A landowner (including the owner of a valid, unpatented mining claim) has a riparian right to the use of water which flows across, rises upon or percolates through his land, insofar as this water has not been previously put to beneficial use by legal appropriators or by other riparian owners farther downstream. The landowner can make any reasonable use of such water upon his riparian land, that does not deprive the prior claimant of the quantity and quality of water to which he is entitled. This includes consumptive use of any unclaimed part of the flow. No formality is required for such riparian use.

Where the water does not naturally flow across the land but is brought to it by diversion from an outside point, such appropriation should be made according to state law. This law is administered by the State Division of Water Resources, Department of Public Works, 401 Public Works Building, Sacramento, to whom requests for information and necessary forms should be addressed.

o

JOURNAL
VOLUME 46 PLATE 23

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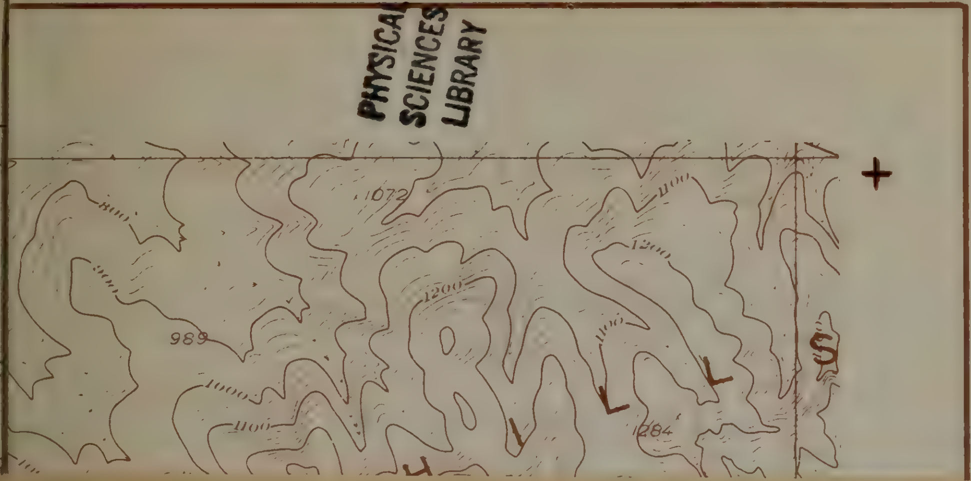
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Collate 16 maps

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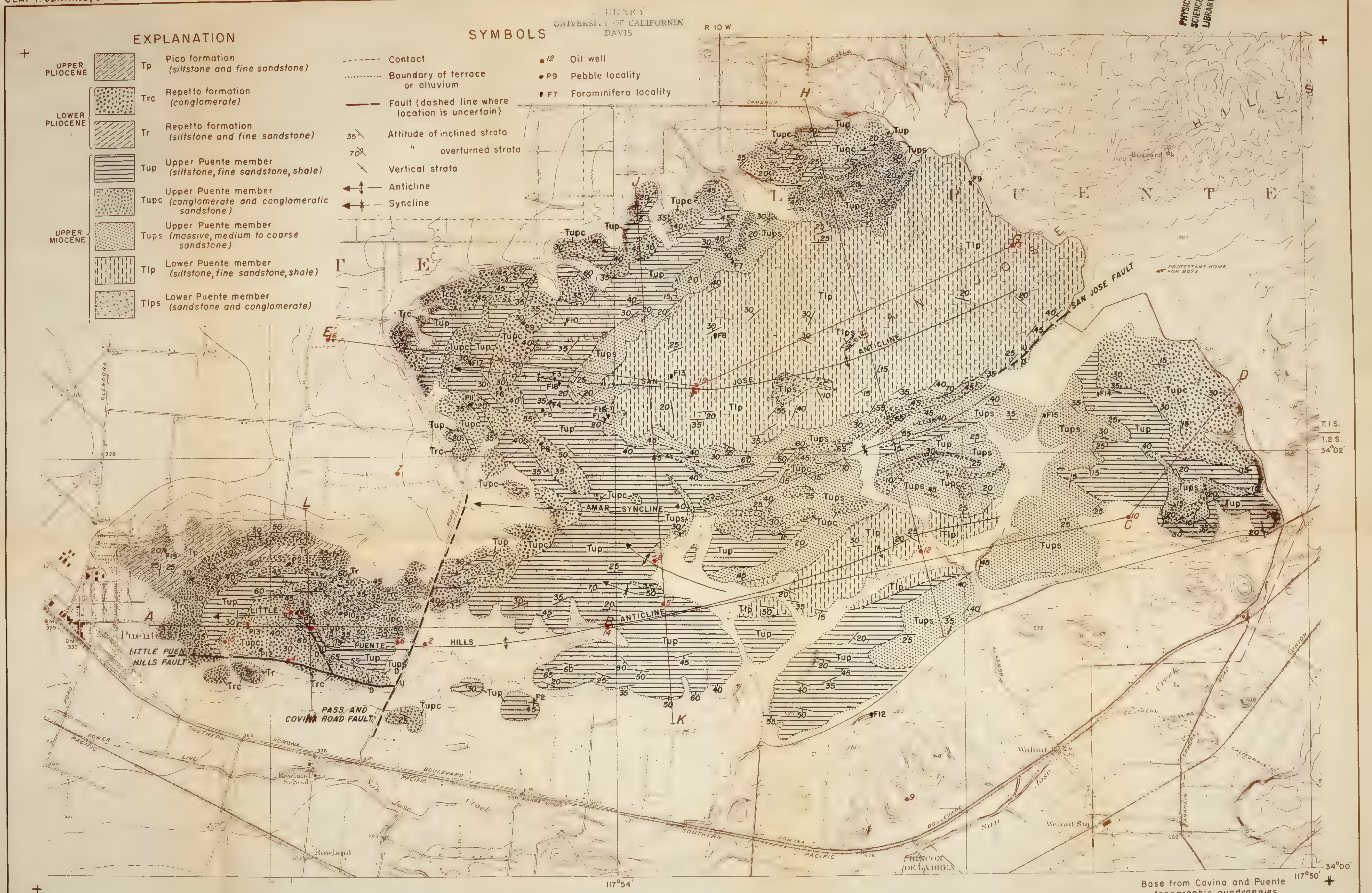

EXPLANATION

Age	Symbol	Unit
UPPER PLIOCENE	Tp	Pico formation (siltstone and fine sandstone)
LOWER PLIOCENE	Trc	Repetto formation (conglomerate)
	Tr	Repetto formation (siltstone and fine sandstone)
UPPER MIOCENE	Tup	Upper Puente member (siltstone, fine sandstone, shale)
	Tupc	Upper Puente member (conglomerate and conglomeratic sandstone)
	Tups	Upper Puente member (massive, medium to coarse sandstone)
	Tlp	Lower Puente member (siltstone, fine sandstone, shale)
	Tlps	Lower Puente member (sandstone and conglomerate)

SYMBOLS

- Contact
- Boundary of terrace or alluvium
- Fault (dashed line where location is uncertain)
- 35 Attitude of inclined strata
- 70 " overturned strata
- Vertical strata
- Anticline
- Syncline
- ● 12 Oil well
- ● P9 Pebble locality
- ● F7 Foraminifera locality

R 10 W.
SAN JOSE HILLS
PUENTE
SAN JOSE ANTICLINE
SAN JOSE FAULT
AMAR SYNCLINE
PUENTE HILLS ANTICLINE
LITTLE PUENTE HILLS FAULT
PASS AND COVINA ROAD FAULT
Buzzard Pk
PROTESTANT HOME FOR BOYS
Puente
Rowland School
Rowland
Walnut
Walnut Sta
RINCON DE LA BREA
SOUTHERN PACIFIC
POMONA BOULEVARD
San Jose Creek
T. 1 S.
T. 2 S.
34°02'
34°00'
117°54'
117°50'
A
B
C
D
E
H
J
K
L
Tp
Trc
Tr
Tup
Tupc
Tups
Tlp
Tlps

GEOLOGIC MAP OF THE WESTERN SAN JOSE HILLS, LOS ANGELES COUNTY, CALIFORNIA

Base from Covina and Puente
topographic quadrangles
Geology by F.H.Olmstead 1948

Scale $\frac{1}{24000}$

1 ½ 0 1 Mile

5000 4000 3000 2000 1000 0 5000 Feet

Contour interval 5 feet and 25 feet (see diagram)

Datum is mean sea level

DIVISION OF MINES
OLAF P. JENKINS, CHIEF

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

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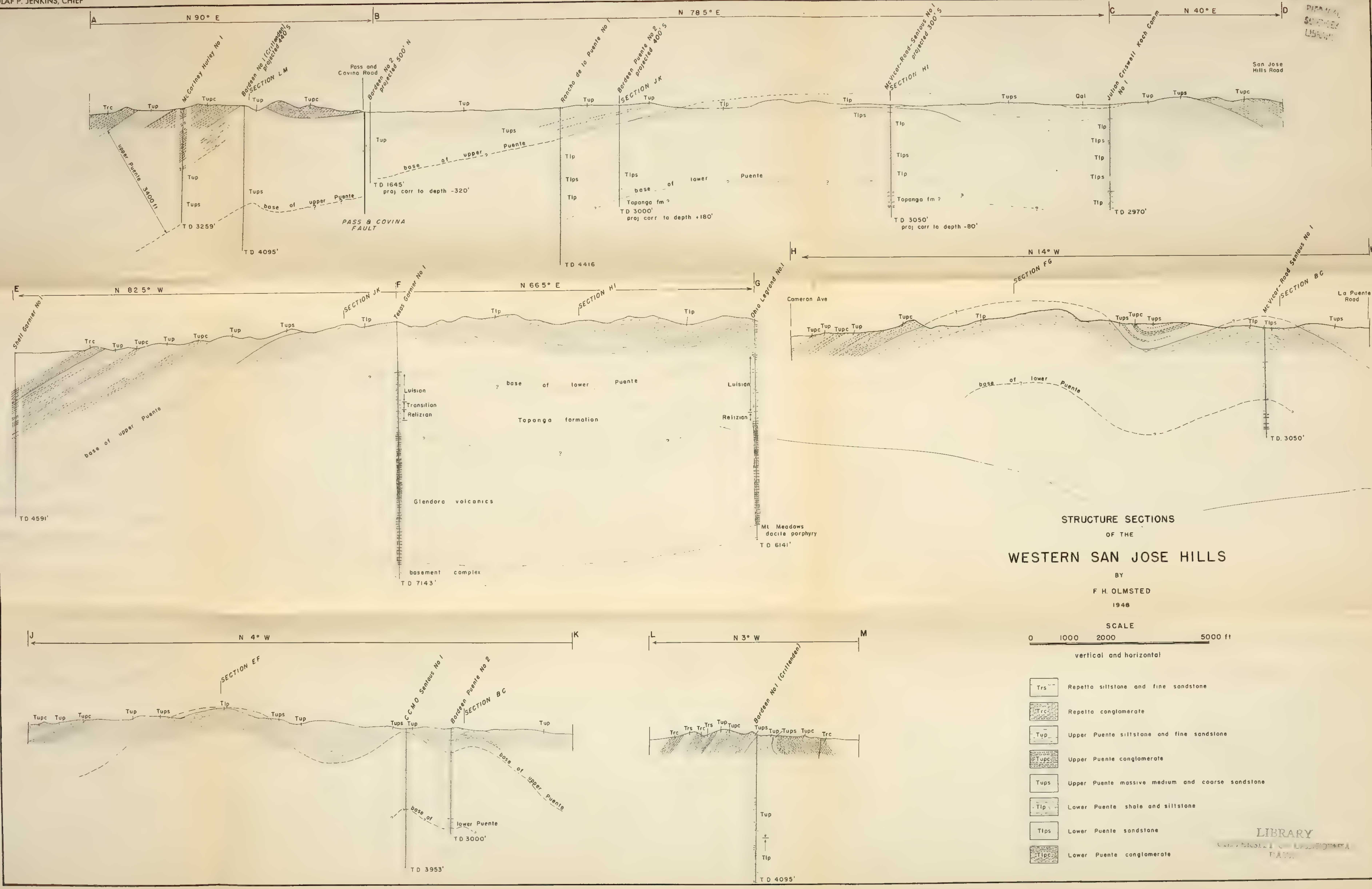
JOURNAL
VOLUME 46 PLATE 24



A
N 90° E
B
N 78.5° E
C
N 40° E
D
McCartney Hurley No 1
Bardeen No 1 (Crittenden) projected 440 S
SECTION LM
Pass and Covina Road
Bardeen No 2 projected 500 N
Rancho de la Puente No 1
Bardeen Puente No 2 projected 400 S
SECTION JK
McVicar-Road-Senious No 1 projected 300 S
SECTION HI
Julian Criswell Koch Comm No 1
San Jose Hills Road
Trc
Tup
Tupc
Tups
Tlp
Tlps
Qal
upper Puente 3400 ft
base of upper Puente
base of lower Puente
Topanga fm ?
PASS & COVINA FAULT
T D 3259'
T D 4095'
T D 1645' proj corr to depth -320'
T D 4416
T D 3000' proj corr to depth +180'
T D 3050' proj corr to depth -80'
T D 2970'
E
N 82.5° W
F
N 66.5° E
G
Shell Garnier No 1
SECTION JK
Texas Garnier No 1
SECTION HI
Ohio Legrand No 1
Luision
Transition
Relizian
Topanga formation
Glendora volcanics
Mt Meadows dacite porphyry
basement complex
T D 4591'
T D 7143'
T D 6141'
H
N 14° W
I
SECTION FG
Cameron Ave
McVicar-Road Senious No 1
SECTION BC
La Puente Road
T D 3050'
J
N 4° W
K
SECTION EF
C C M O Senious No 1
Bardeen Puente No 2
SECTION BC
base of upper Puente
base of lower Puente
T D 3000'
T D 3953'
L
N 3° W
M
Bardeen No 1 (Crittenden)
Trs
T D 4095'

STRUCTURE SECTIONS
OF THE
WESTERN SAN JOSE HILLS
BY
F. H. OLMSTED
1948

SCALE
0 1000 2000 5000 ft
vertical and horizontal

Trs	Repetto siltstone and fine sandstone
Trc	Repetto conglomerate
Tup	Upper Puente siltstone and fine sandstone
Tupc	Upper Puente conglomerate
Tups	Upper Puente massive medium and coarse sandstone
Tlp	Lower Puente shale and siltstone
Tlps	Lower Puente sandstone
Tlpc	Lower Puente conglomerate

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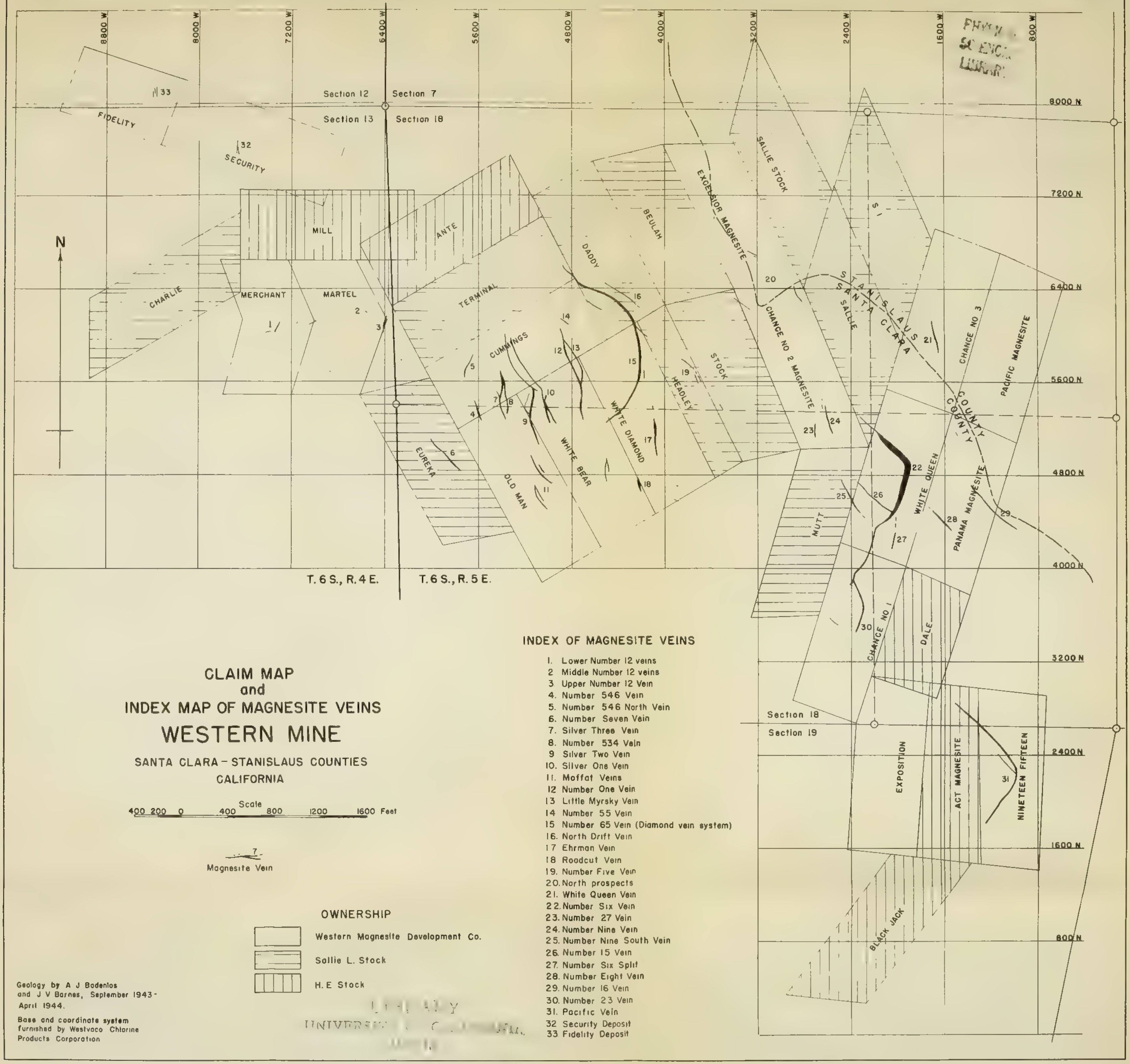
8800 W
8000 W
7200 W
6400 W
5600 W
4800 W
4000 W
3200 W
2400 W
1600 W
800 W
8000 N
7200 N
6400 N
5600 N
4800 N
4000 N
3200 N
2400 N
1600 N
800 N
N
Section 12
Section 7
Section 13
Section 18
Section 18
Section 19
T.6 S., R.4 E.
T.6 S., R.5 E.
FIDELITY
SECURITY
MILL
CHARLIE
MERCHANT
MARTEL
ANTE
TERMINAL
CUMMINGS
EUREKA
OLD MAN
WHITE BEAR
WHITE DIAMOND
DADDY
BEULAH
EXCELSIOR MAGNESITE
SALLIE STOCK
HEADLEY
STOCK
CHANCE NO 2 MAGNESITE
STANISLAUS
SANTA CLARA
SALLIE
COUNTY
CHANCE NO 3
PACIFIC MAGNESITE
WHITE QUEEN
PANAMA MAGNESITE
MUTT
CHANCE NO 1
DALE
EXPOSITION
ACT MAGNESITE
NINETEEN FIFTEEN
BLACK JACK
1
2
3
4
5
6
7
8
9
10
11
12
13
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32
33

CLAIM MAP
and
INDEX MAP OF MAGNESITE VEINS
WESTERN MINE

SANTA CLARA – STANISLAUS COUNTIES
CALIFORNIA

Scale
400 200 0 400 800 1200 1600 Feet

7
Magnesite Vein

INDEX OF MAGNESITE VEINS

1. Lower Number 12 veins
2. Middle Number 12 veins
3. Upper Number 12 Vein
4. Number 546 Vein
5. Number 546 North Vein
6. Number Seven Vein
7. Silver Three Vein
8. Number 534 Vein
9. Silver Two Vein
10. Silver One Vein
11. Moffat Veins
12. Number One Vein
13. Little Myrsky Vein
14. Number 55 Vein
15. Number 65 Vein (Diamond vein system)
16. North Drift Vein
17. Ehrman Vein
18. Roadcut Vein
19. Number Five Vein
20. North prospects
21. White Queen Vein
22. Number Six Vein
23. Number 27 Vein
24. Number Nine Vein
25. Number Nine South Vein
26. Number 15 Vein
27. Number Six Split
28. Number Eight Vein
29. Number 16 Vein
30. Number 23 Vein
31. Pacific Vein
32. Security Deposit
33. Fidelity Deposit

OWNERSHIP

☐ Western Magnesite Development Co.
▤ Sallie L. Stock
▥ H. E Stock

Geology by A J Bodenlos
and J V Barnes, September 1943 -
April 1944.

Base and coordinate system
furnished by Westvaco Chlorine
Products Corporation

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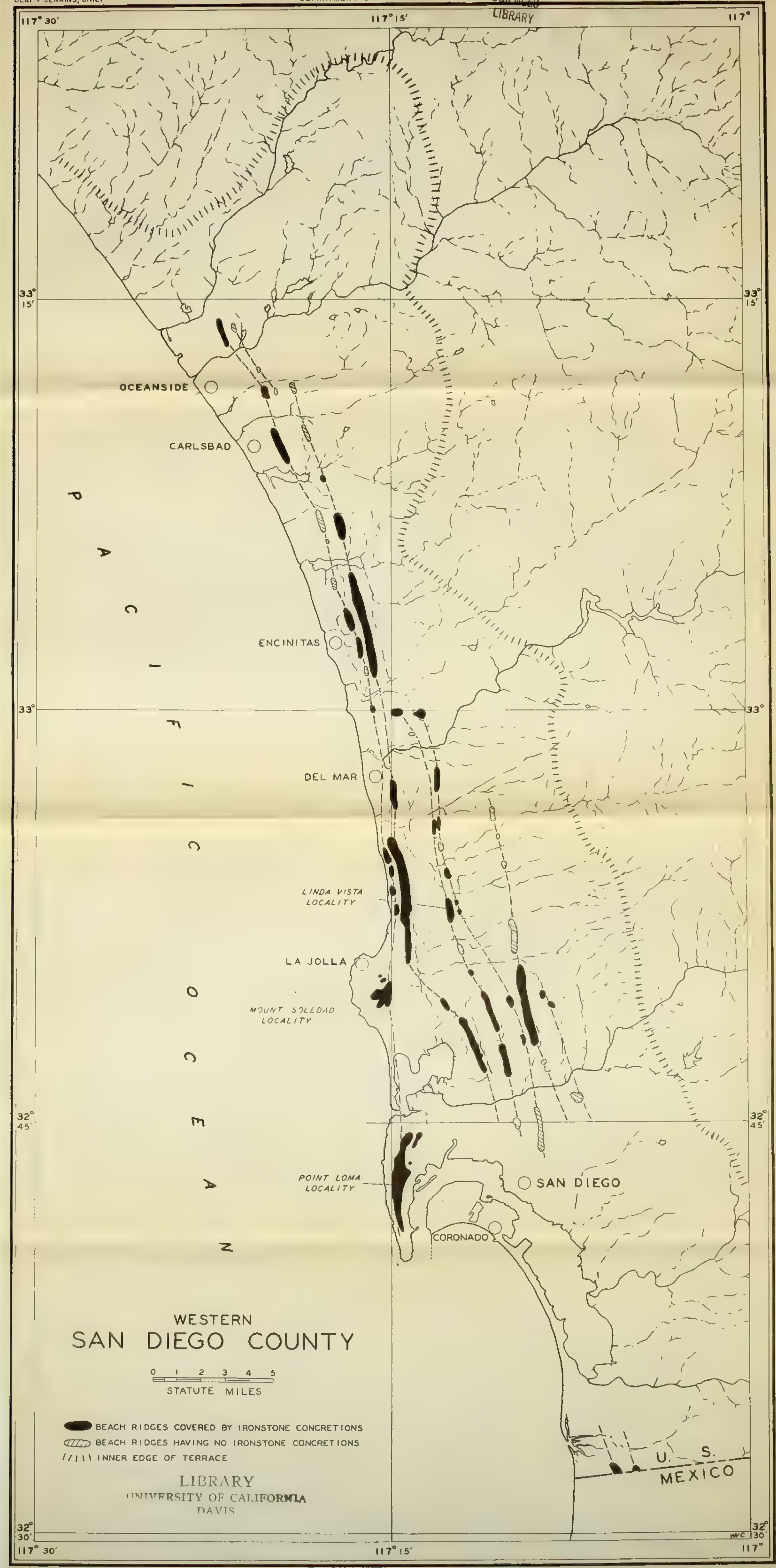
117° 30'
117° 15'
117°
33° 15'
33°
32° 45'
32° 30'
OCEANSIDE
CARLSBAD
ENCINITAS
DEL MAR
LINDA VISTA LOCALITY
LA JOLLA
MOUNT SOLEDAD LOCALITY
POINT LOMA LOCALITY
SAN DIEGO
CORONADO
PACIFIC OCEAN
U. S.
MEXICO
0 1 2 3 4 5
STATUTE MILES
BEACH RIDGES COVERED BY IRONSTONE CONCRETIONS
BEACH RIDGES HAVING NO IRONSTONE CONCRETIONS
INNER EDGE OF TERRACE
WC

WESTERN
SAN DIEGO COUNTY

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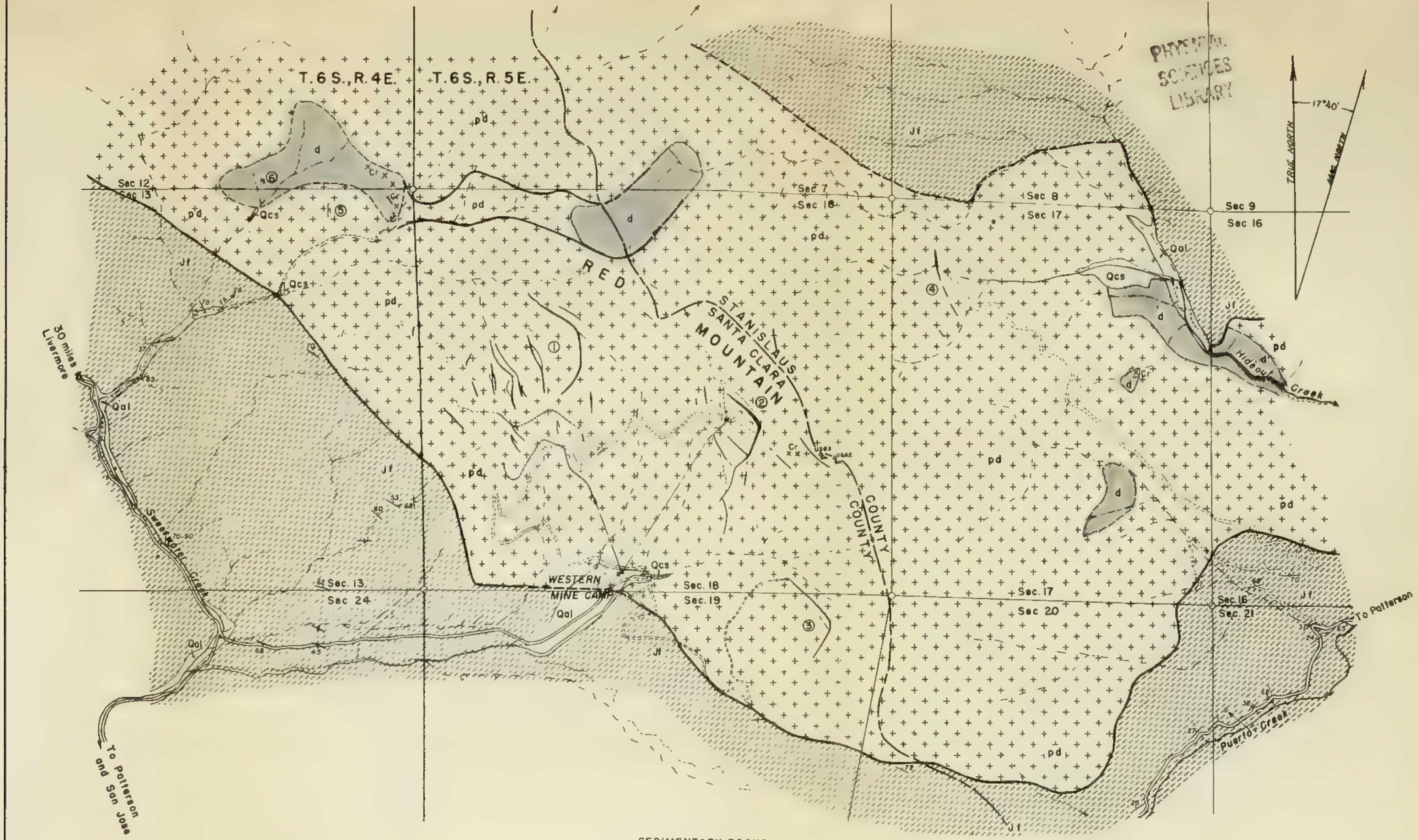
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T.6 S., R.5 E.
Sec 12
Sec 13
Sec 7
Sec 18
Sec 8
Sec 17
Sec 9
Sec 16
Sec. 13
Sec 24
Sec. 18
Sec. 19
Sec. 17
Sec 20
Sec 16
Sec. 21
RED MOUNTAIN
STANISLAUS
SANTA CLARA
COUNTY
COUNTY
WESTERN MINE CAMP
TRUE NORTH
MAG. NORTH
17°40'
30 miles to Livermore
To Patterson and San Jose
To Patterson
Sweetwater Creek
Hideout Creek
Puerto Creek
pd
d
Jf
Qcs
Qal
Cr
①
②
③
④
⑤
⑥
SEDIMENTARY ROCKS
Qal
Recent stream deposits
Qcs
Calcareous sinter
QUATERNARY
Jf
Franciscan group
IGNEOUS ROCKS
d
Dunite
pd
Peridotite
Jurassic(?)
MINERAL DEPOSITS
Magnesite
Cr
Chromite prospect
SYMBOLS
27
Strike and dip of beds
Strike of vertical beds
FA 6
Plunge of fold axis
Fault
Contact
Trail
Overhead tram
Railroad

MAGNESITE DEPOSITS

① Diamond-Silver group, Western Mine
② Number Six-White Queen group, Western Mine
③ Pacific Vein, Western Mine
④ Red Mountain Mine
⑤ Security Deposit
⑥ Fidelity Deposit

GEOLOGIC MAP
of the
RED MOUNTAIN MAGNESITE DISTRICT
SANTA CLARA and STANISLAUS COUNTIES
CALIFORNIA

Scale
1000 0 1000 2000 3000 Feet

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Note: County line follows watershed, fixed by act of California State Legislature

Geology by A. J Bodenlos and
J V Barnes, Sept. 1943-
April 1944
Base controlled mosaic from
U S. A A A aerial
photographs

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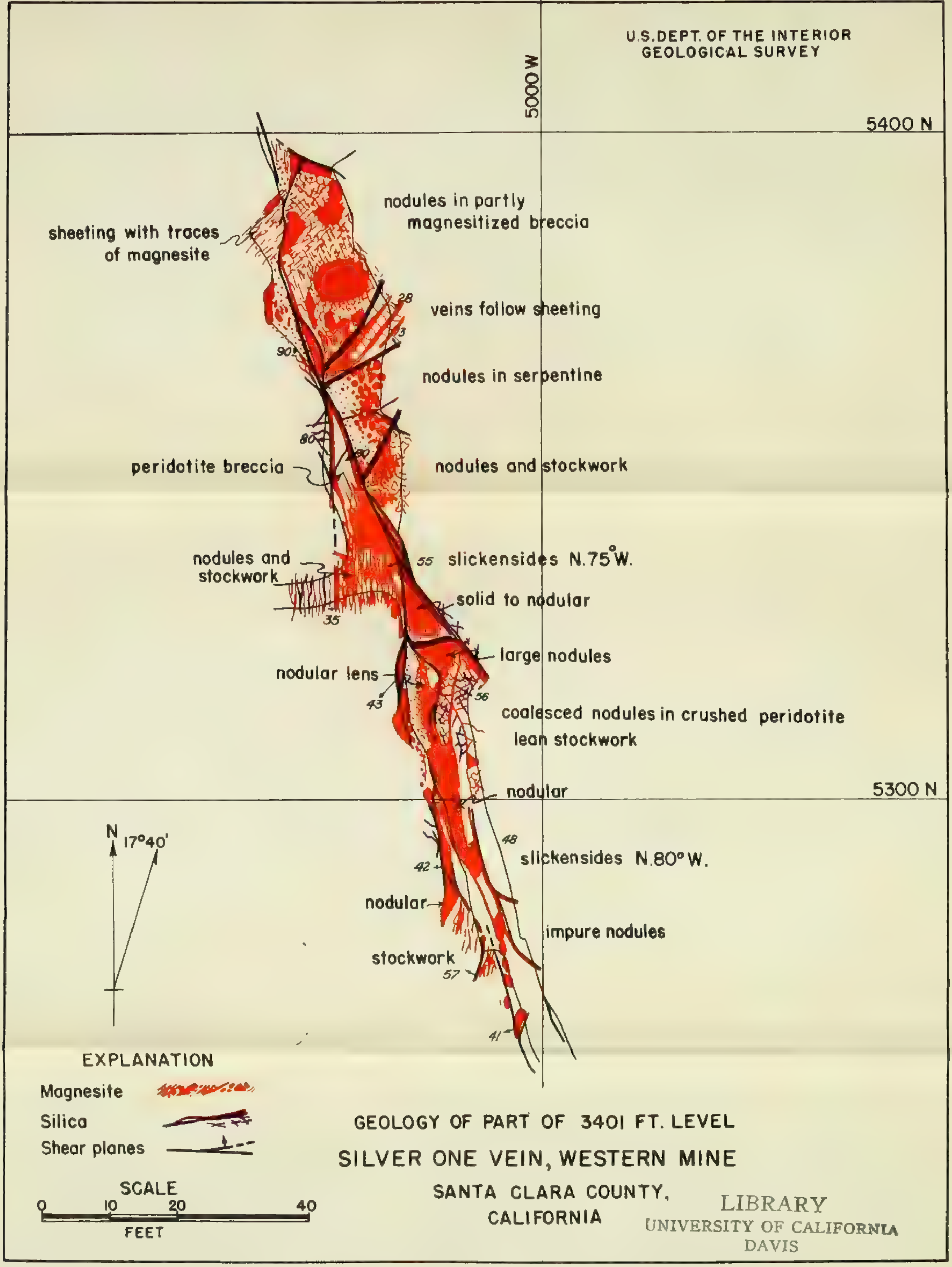
5000 W
5400 N
5300 N
nodules in partly magnesitized breccia
sheeting with traces of magnesite
28
veins follow sheeting
3
90
nodules in serpentine
80
80
peridotite breccia
nodules and stockwork
nodules and stockwork
55
slickensides N.75°W.
35
solid to nodular
large nodules
nodular lens
56
43
coalesced nodules in crushed peridotite
lean stockwork
nodular
N
17°40'
48
slickensides N.80°W.
42
nodular
impure nodules
stockwork
57
41
EXPLANATION
Magnesite
Silica
Shear planes
SCALE
0
10
20
40
FEET

U.S. DEPT. OF THE INTERIOR
GEOLOGICAL SURVEY

GEOLOGY OF PART OF 3401 FT. LEVEL

SILVER ONE VEIN, WESTERN MINE

SANTA CLARA COUNTY,
CALIFORNIA

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MAGNESITE IN A STRONG SHEAR AND BRECCIA ZONE

DIVISION OF MINES
OLAF P. JENKINS, CHIEF

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UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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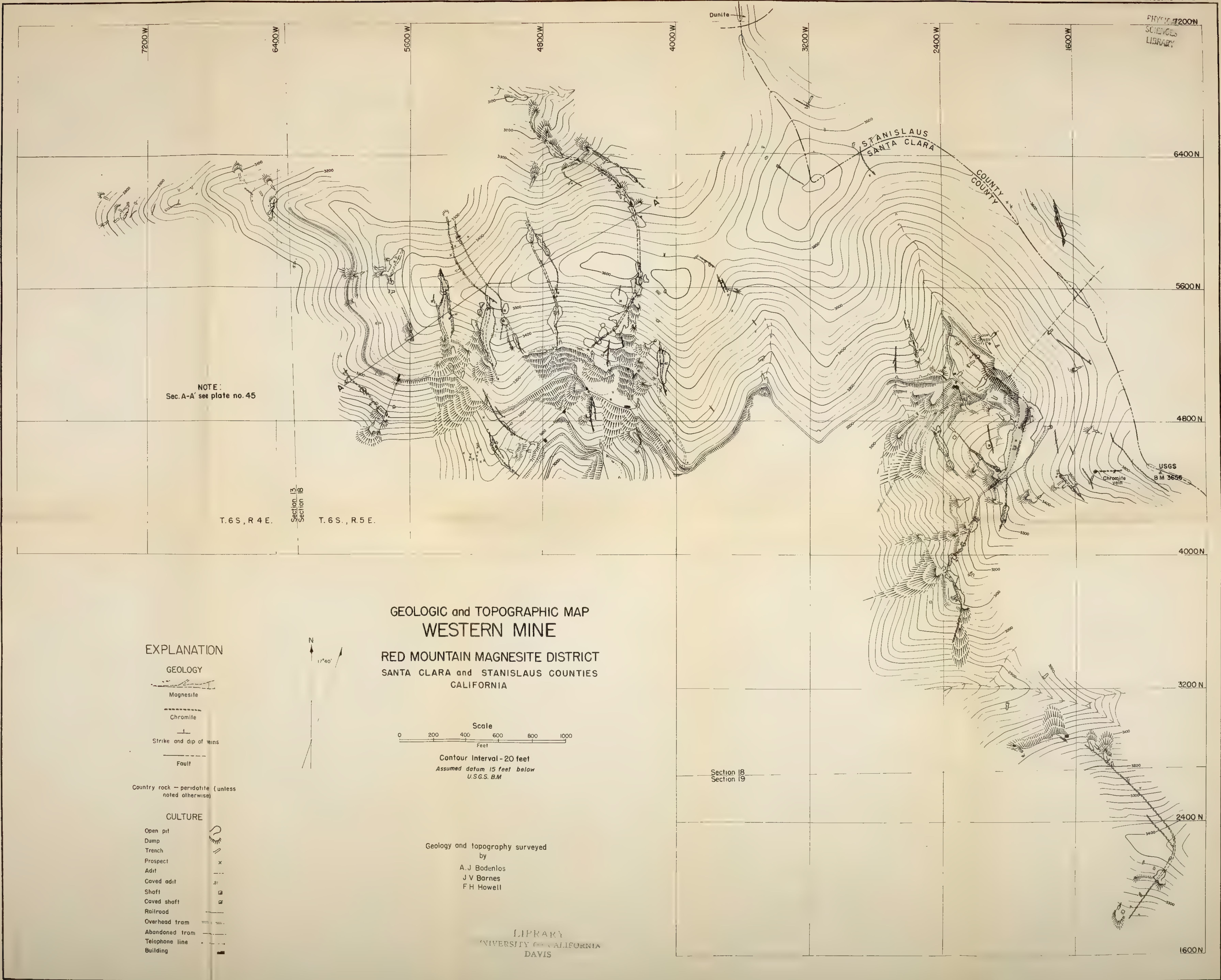
7200 W
6400 W
5600 W
4800 W
4000 W
3200 W
2400 W
1600 W
7200 N
6400 N
5600 N
4800 N
4000 N
3200 N
2400 N
1600 N
Dunite
STANISLAUS COUNTY
SANTA CLARA COUNTY
A
A'
NOTE:
Sec. A-A' see plate no. 45
T.6S., R4E.
Section 13
Section 18
T.6S., R5E.
USGS
BM 3656
Chromite vein
Section 18
Section 19
N
17°40'

GEOLOGIC and TOPOGRAPHIC MAP
WESTERN MINE
RED MOUNTAIN MAGNESITE DISTRICT
SANTA CLARA and STANISLAUS COUNTIES
CALIFORNIA

Scale
0 200 400 600 800 1000
Feet

Contour Interval - 20 feet
Assumed datum 15 feet below U.S.G.S. B.M

EXPLANATION

GEOLOGY

Magnesite

Chromite

Strike and dip of veins

Fault

Country rock — peridotite (unless noted otherwise)

CULTURE

- Open pit
- Dump
- Trench
- Prospect ×
- Adit
- Caved adit
- Shaft
- Caved shaft
- Railroad
- Overhead tram
- Abandoned tram
- Telephone line
- Building ▬

Geology and topography surveyed
by
A. J. Bodenlos
J. V. Barnes
F. H. Howell

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GEOLOGIC LEVEL MAPS
WHITE DIAMOND-SILVER WORKINGS
3040, 3090, 3160, 3240 LEVELS
WESTERN MINE
SANTA CLARA-STANISLAUS COUNTIES CALIFORNIA

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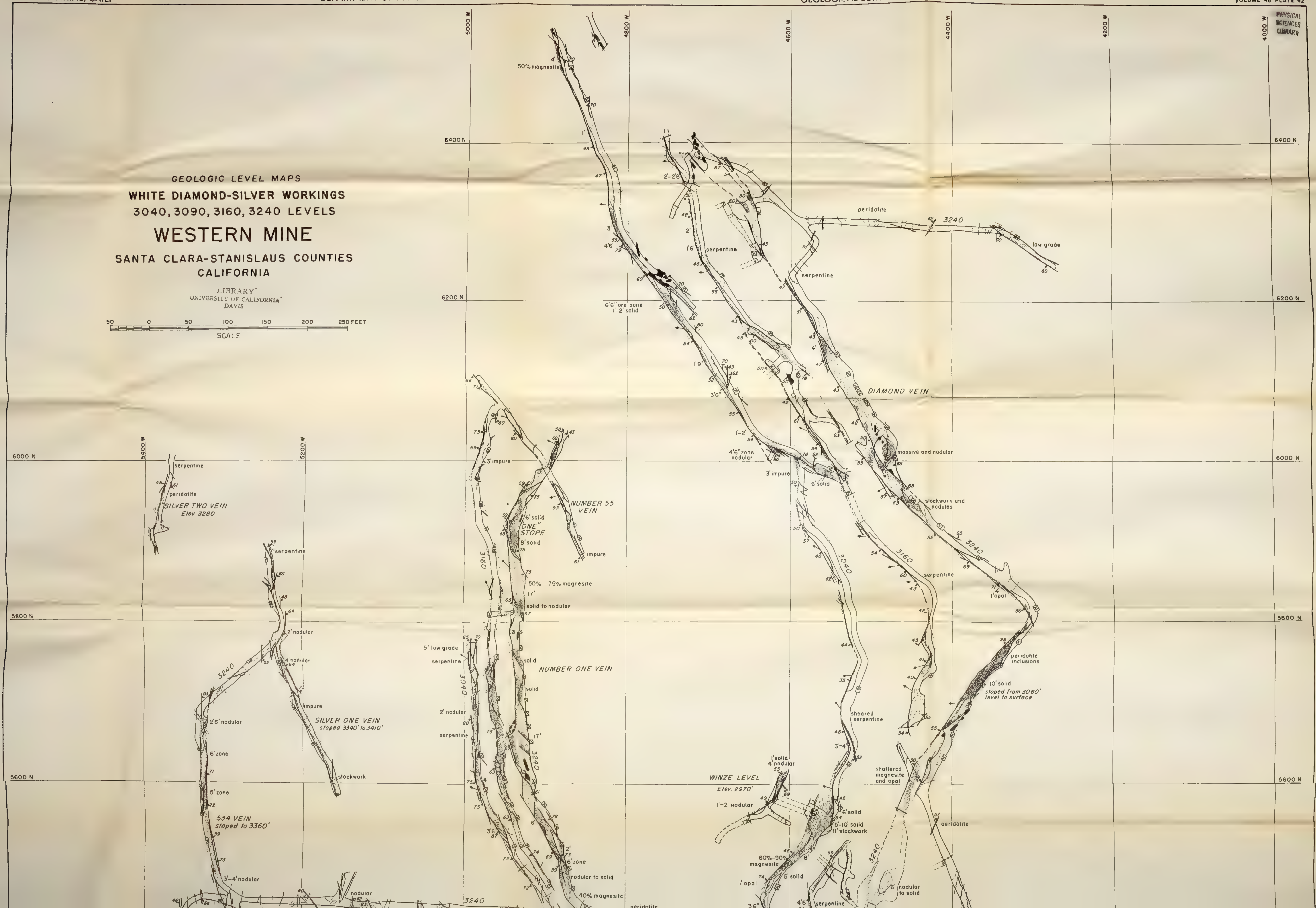
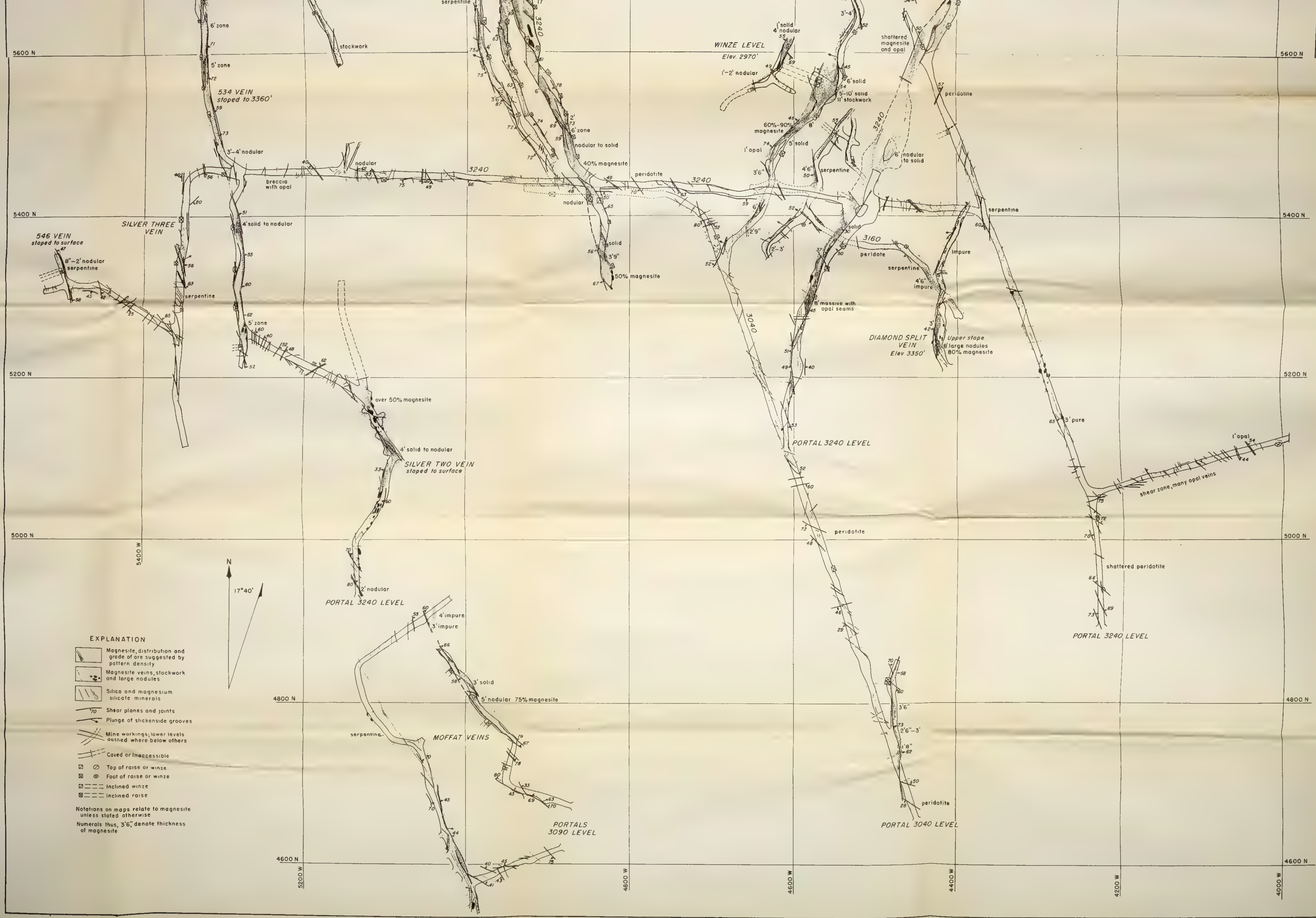

50 0 50 100 150 200 250 FEET
SCALE
5400 W
5200 W
5000 W
4800 W
4600 W
4400 W
4200 W
4000 W
6400 N
6200 N
6000 N
5800 N
5600 N
50% magnesite
peridotite
3240
low grade
serpentine
6'6" ore zone
1'-2' solid
DIAMOND VEIN
massive and nodular
4'6" zone nodular
3' impure
6' solid
stockwork and nodules
3160
3040
serpentine
1' opal
peridotite inclusions
10' solid
stoped from 3060' level to surface
sheared serpentine
WINZE LEVEL
Elev. 2970'
1'-2' nodular
1' solid
4' nodular
shattered magnesite and opal
6' solid
5-10' solid
11' stockwork
60%-90% magnesite
5' solid
1' opal
4'6"
serpentine
6' nodular to solid
peridotite
3' impure
NUMBER 55 VEIN
impure
6' solid
"ONE" STOPE
8' solid
50%-75% magnesite
17'
solid to nodular
5' low grade
serpentine
solid
NUMBER ONE VEIN
2' nodular
serpentine
17'
6' zone
nodular to solid
40% magnesite
peridotite
SILVER TWO VEIN
Elev 3280
serpentine
2' nodular
4' nodular
impure
SILVER ONE VEIN
stoped 3340' to 3410'
stockwork
2'6" nodular
6' zone
5' zone
534 VEIN
stoped to 3360'
3'-4' nodular
nodular


EXPLANATION
Magnesite, distribution and grade of ore suggested by pattern density
Magnesite veins, stockwork and large nodules
Silica and magnesium silicate minerals
Shear planes and joints
Plunge of slickenside grooves
Mine workings; lower levels dashed where below others
Caved or inaccessible
Top of raise or winze
Foot of raise or winze
Inclined winze
Inclined raise
Notations on maps relate to magnesite unless stated otherwise
Numerals thus, 3'6", denote thickness of magnesite
534 VEIN
stoped to 3360'
546 VEIN
stoped to surface
SILVER THREE VEIN
SILVER TWO VEIN
stoped to surface
MOFFAT VEINS
WINZE LEVEL
Elev. 2970'
DIAMOND SPLIT VEIN
Elev 3350'
Upper stope
PORTAL 3240 LEVEL
PORTAL 3240 LEVEL
PORTAL 3240 LEVEL
PORTAL 3040 LEVEL
PORTALS
3090 LEVEL
3240
3160
3040
17°40'
N
5600 N
5400 N
5200 N
5000 N
4800 N
4600 N
5400 W
5200 W
4800 W
4600 W
4400 W
4200 W
4000 W
serpentine
stockwork
6' zone
5' zone
3'-4' nodular
breccia with opal
nodular
peridotite
40% magnesite
nodular to solid
6' zone
solid
3'9"
50% magnesite
4' solid to nodular
8"-2' nodular
serpentine
over 50% magnesite
4' solid to nodular
2' nodular
4' impure
3' impure
3' solid
5' nodular 75% magnesite
shattered magnesite and opal
1' solid
4' nodular
1'-2' nodular
6' solid
5-10' solid
11' stockwork
60%-90% magnesite
5' solid
1' opal
3'6"
4'6"
6' nodular to solid
2'9"
2'-3'
8' massive with opal seams
8' large nodules 80% magnesite
impure
4'6" impure
3' pure
1' opal
shear zone, many opal veins
shattered peridotite
3'6"
2'6"-3'
1'8"

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UNITED STATES DEPARTMENT OF THE INTERIOR
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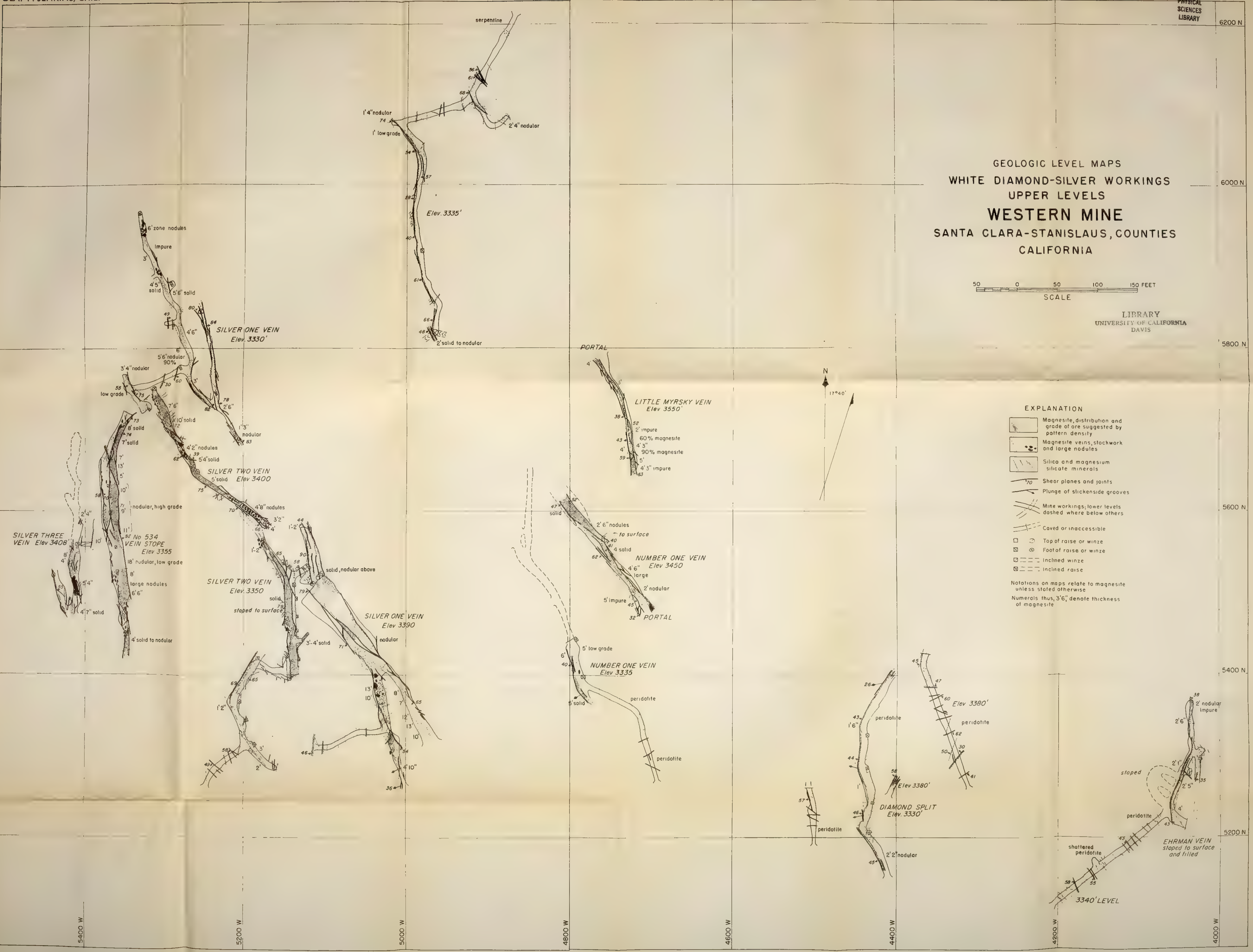
GEOLOGIC LEVEL MAPS
WHITE DIAMOND-SILVER WORKINGS
UPPER LEVELS
WESTERN MINE
SANTA CLARA-STANISLAUS, COUNTIES
CALIFORNIA


6200 N
6000 N
5800 N
5600 N
5400 N
5200 N
5400 W
5200 W
5000 W
4800 W
4600 W
4400 W
4200 W
4000 W
50 0 50 100 150 FEET
SCALE
N
17°40'
serpentine
1'4" nodular
1' low grade
2'4" nodular
Elev. 3335'
2' solid to nodular
6' zone nodules
Impure
3'
4'5" solid
5'6" solid
4'6"
SILVER ONE VEIN
Elev. 3330'
5'6" nodular 90%
3'4" nodular
low grade
7'6"
10' solid
2'6"
1'3" nodular
8' solid
7' solid
4'2" nodules
5'4" solid
SILVER TWO VEIN
5' solid Elev 3400
4'8" nodules
3'2"
4'
nodular, high grade
SILVER THREE VEIN Elev 3408'
2'4"
10'
No 534 VEIN STOPE
Elev 3355
18' nodular, low grade
large nodules
6'6"
5'4"
4'7" solid
4' solid to nodular
1'-2'
solid, nodular above
SILVER TWO VEIN
Elev. 3350
solid
stoped to surface
SILVER ONE VEIN
Elev 3390
nodular
3'-4' solid
1'2"
2'
13'
10'
8'
7'
12'
13'
10'
4'10"
PORTAL
LITTLE MYRSKY VEIN
Elev 3550'
2' impure
60% magnesite
4'3"
90% magnesite
4'3" impure
solid
2'6" nodules
to surface
4 solid
NUMBER ONE VEIN
Elev 3450
4'6" large
2' nodular
5' impure
PORTAL
5' low grade
NUMBER ONE VEIN
Elev 3335
5' solid
peridotite
peridotite
peridotite
1'6"
Elev 3380'
Elev 3380'
DIAMOND SPLIT
Elev. 3330'
2'2" nodular
peridotite
2' nodular impure
2'6"
stoped
2'1"
2'5"
peridotite
shattered peridotite
EHRMAN VEIN
stoped to surface and filled
3340' LEVEL
EXPLANATION
Magnesite, distribution and grade of ore suggested by pattern density
Magnesite veins, stockwork and large nodules
Silica and magnesium silicate minerals
70 Shear planes and joints
Plunge of slickenside grooves
Mine workings; lower levels dashed where below others
Caved or inaccessible
Top of raise or winze
Foot of raise or winze
Inclined winze
Inclined raise
Notations on maps relate to magnesite unless stated otherwise
Numerals thus, 3'6", denote thickness of magnesite

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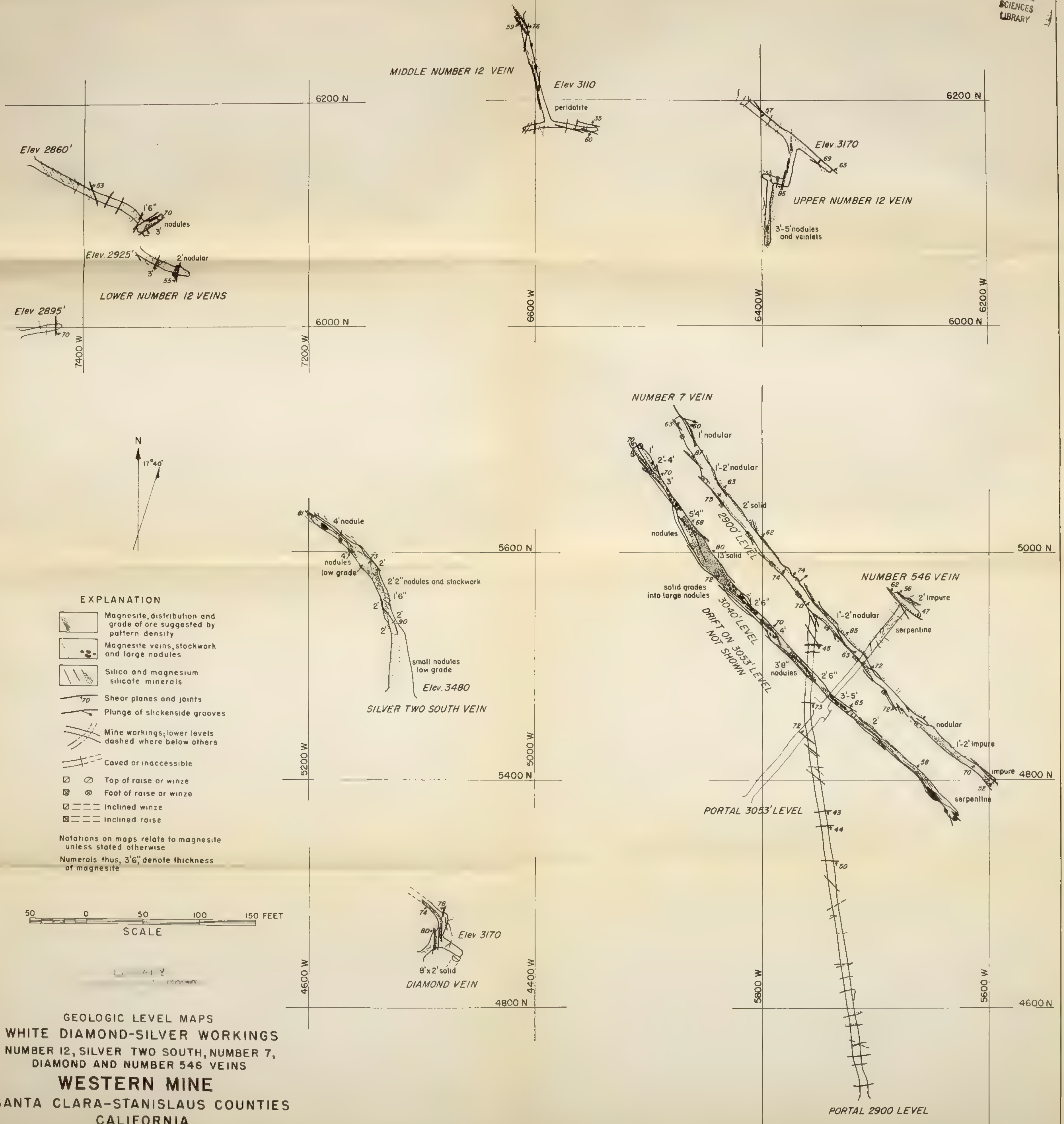
MIDDLE NUMBER 12 VEIN
59
76
Elev 3110
peridotite
35
60
6200 N
Elev 2860'
53
1'6"
70
nodules
3'
Elev. 2925'
2'nodular
3'
55
LOWER NUMBER 12 VEINS
Elev 2895'
70
6000 N
7400 W
7200 W
57
Elev. 3170
69
63
65
UPPER NUMBER 12 VEIN
3'-5'nodules
and veinlets
6200 N
6600 W
6400 W
6200 W
6000 N
N
17°40'
81
4'nodule
4'
nodules
low grade
73
2'
2'2" nodules and stockwork
1'6"
2'
2'
90
2'
small nodules
low grade
Elev. 3480
SILVER TWO SOUTH VEIN
5600 N
5200 W
5000 W
5400 N
NUMBER 7 VEIN
63
60
1' nodular
70
1'
2'-4'
70
3'
67
1'-2' nodular
63
75
2' solid
5'4"
68
nodules
2900' LEVEL
62
80
13' solid
72
solid grades
into large nodules
3040' LEVEL
DRIFT ON 3053' LEVEL
NOT SHOWN
2'6"
74
74
70
70
4'
1'-2' nodular
85
45
63
3'8"
nodules
2'6"
72
3'-5'
65
73
2'
72
72
nodular
1'-2' impure
58
70
impure
52
serpentine
NUMBER 546 VEIN
62
56
2' impure
47
serpentine
5000 N
4800 N
PORTAL 3053' LEVEL
43
44
50
PORTAL 2900 LEVEL
5800 W
5600 W
4600 N
78
74
80
Elev 3170
8'x2' solid
DIAMOND VEIN
4600 W
4400 W
4800 N
EXPLANATION
▨ Magnesite, distribution and grade of ore suggested by pattern density
● Magnesite veins, stockwork and large nodules
▨ Silica and magnesium silicate minerals
70 Shear planes and joints
Plunge of slickenside grooves
Mine workings; lower levels dashed where below others
Caved or inaccessible
⊘ Top of raise or winze
⊠ ⊗ Foot of raise or winze
⊘ — — — Inclined winze
⊠ — — — Inclined raise
Notations on maps relate to magnesite unless stated otherwise
Numerals thus, 3'6", denote thickness of magnesite
50
0
50
100
150 FEET
SCALE

GEOLOGIC LEVEL MAPS
WHITE DIAMOND-SILVER WORKINGS
NUMBER 12, SILVER TWO SOUTH, NUMBER 7,
DIAMOND AND NUMBER 546 VEINS
WESTERN MINE
SANTA CLARA-STANISLAUS COUNTIES
CALIFORNIA

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GEOLOGIC CROSS-SECTION A-A′
WHITE DIAMOND WORKINGS
WESTERN MINE
SANTA CLARA COUNTY, CALIFORNIA

LINE OF SECTION SHOWN ON PLATE 41

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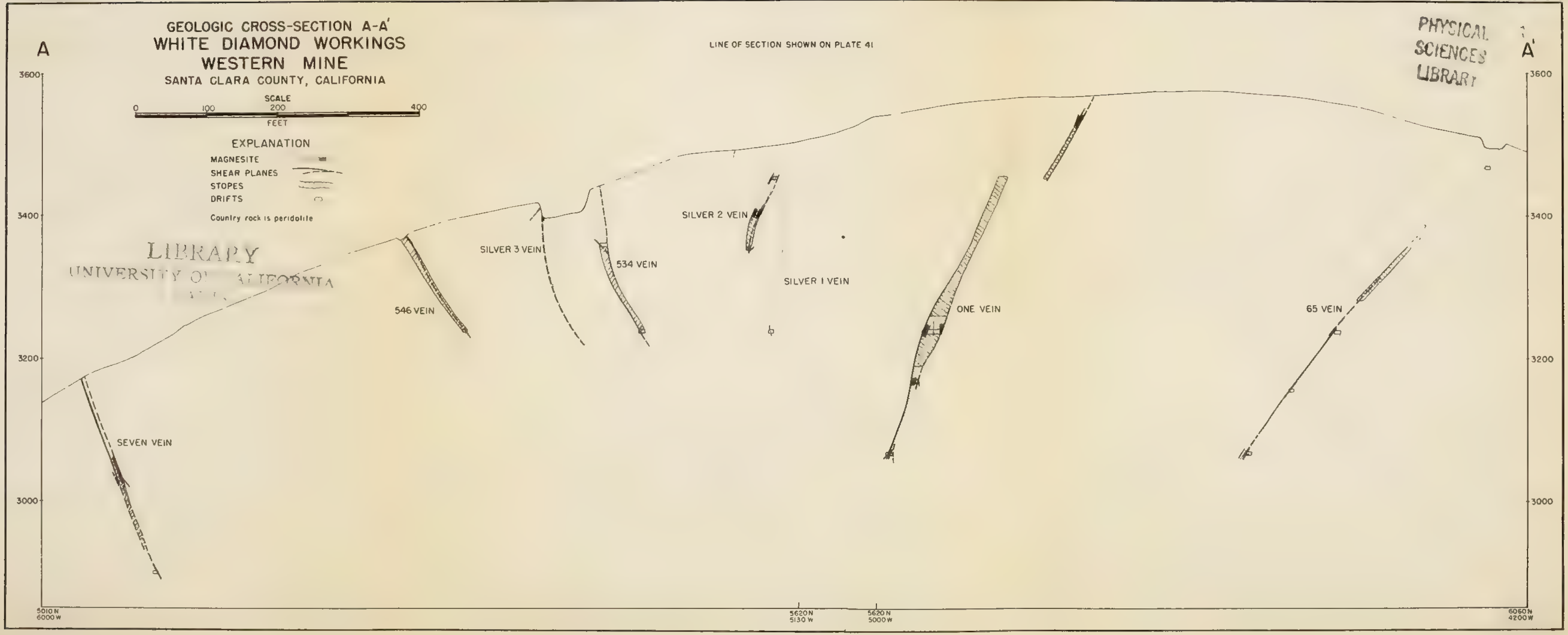
A
A′
SCALE
0
100
200
400
FEET
EXPLANATION
MAGNESITE
SHEAR PLANES
STOPES
DRIFTS
Country rock is peridotite
3600
3400
3200
3000
SEVEN VEIN
546 VEIN
SILVER 3 VEIN
534 VEIN
SILVER 2 VEIN
SILVER 1 VEIN
ONE VEIN
65 VEIN
5010 N
6000 W
5620 N
5130 W
5620 N
5000 W
6060 N
4200 W

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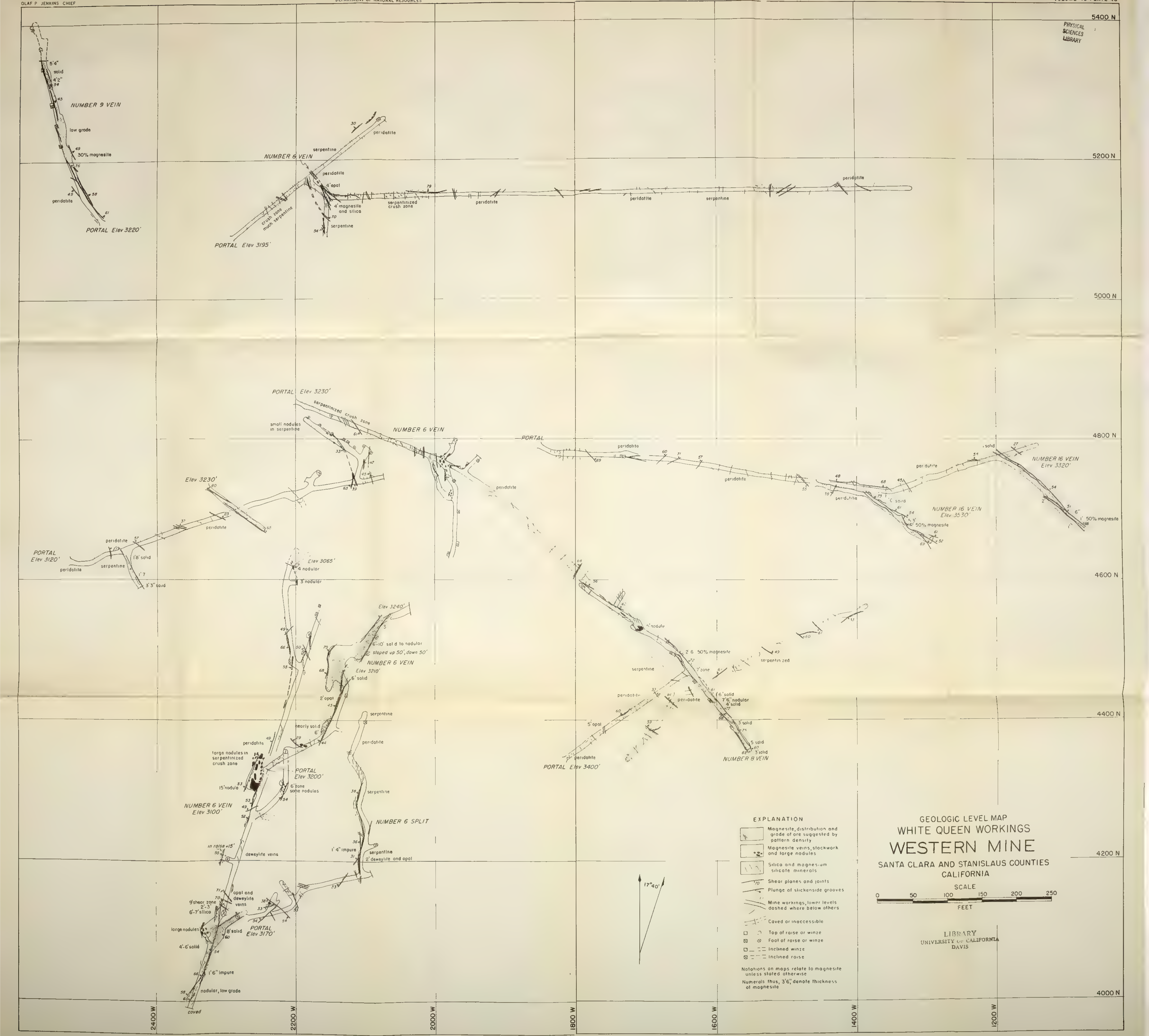
5400 N
5200 N
5000 N
4800 N
4600 N
4400 N
4200 N
4000 N
2400 W
2200 W
2000 W
1800 W
1600 W
1400 W
1200 W
5'4"
solid
4'2"
54
45
NUMBER 9 VEIN
low grade
49
30% magnesite
76
49
58
peridotite
61
PORTAL Elev 3220'
30
peridotite
serpentine
NUMBER 6 VEIN
peridotite
4'opal
4'magnesite
and silica
70
serpentine
54
crush zone
much serpentine
serpentinized
crush zone
79
peridotite
peridotite
serpentine
peridotite
PORTAL Elev 3195'
PORTAL Elev 3230'
serpentinized crush zone
small nodules
in serpentine
61
NUMBER 6 VEIN
33
45
63
39
peridotite
Elev 3230'
80
23
37
peridotite
65
peridotite
57
PORTAL
Elev 3120'
1'8' solid
serpentine
peridotite
1'7
3'3" solid
PORTAL
peridotite
69
60
71
57
peridotite
55
48
18
peridotite
68
45
73
C solid
61
54
5 3'
50% magnesite
61
52
69
per dotite
55
solid
27
NUMBER 16 VEIN
Elev 3320'
NUMBER 16 VEIN
Elev 3530'
54
2'
51
6"
1' 50% magnesite
66
64
56
5'nodule
2 6 50% magnesite
72
serpentine
7'zone
61
49
serpentinized
60
61
33
peridotite
33
61
peridotite
61
6'solid
7'6" nodular
4'solid
72
3'solid
75
5 solid
60
3'solid
82
NUMBER 8 VEIN
60
5'opal
59
peridotite
PORTAL Elev 3400'
Elev 3065'
4 nodular
3'nodular
Elev 3240'
3
6'-10' solid to nodular
stoped up 50', down 50'
NUMBER 6 VEIN
Elev 3210'
6'solid
49
66
50
70
55
68
2'opal
45
serpentine
nearly solid
6'
29
44
peridotite
49
peridotite
large nodules in
serpentinized
crush zone
PORTAL
Elev 3200'
53
15'nodule
6'zone
some nodules
54
53
49
52
NUMBER 6 VEIN
Elev 3100'
38
serpentine
NUMBER 6 SPLIT
36
1'4" impure
serpentine
31
2'deweylite and opal
in raise +15'
55
deweylite veins
33
71
70
opal and
deweylite
veins
9'shear zone
2'-3'
6'-7'silica
38
33
53
54
54
large nodules
8'solid
60
PORTAL
Elev 3170'
4'-6'solid
54
66
1'6" impure
58
60
nodular, low grade
caved
17°40'
EXPLANATION
Magnesite, distribution and grade of ore suggested by pattern density
Magnesite veins, stockwork and large nodules
Silica and magnesium silicate minerals
70
Shear planes and joints
Plunge of slickenside grooves
Mine workings, lower levels dashed where below others
Caved or inaccessible
Top of raise or winze
Foot of raise or winze
Inclined winze
Inclined raise
Notations on maps relate to magnesite unless stated otherwise
Numerals thus, 3'6", denote thickness of magnesite
SCALE
0
50
100
150
200
250
FEET

GEOLOGIC LEVEL MAP
WHITE QUEEN WORKINGS
WESTERN MINE
SANTA CLARA AND STANISLAUS COUNTIES
CALIFORNIA

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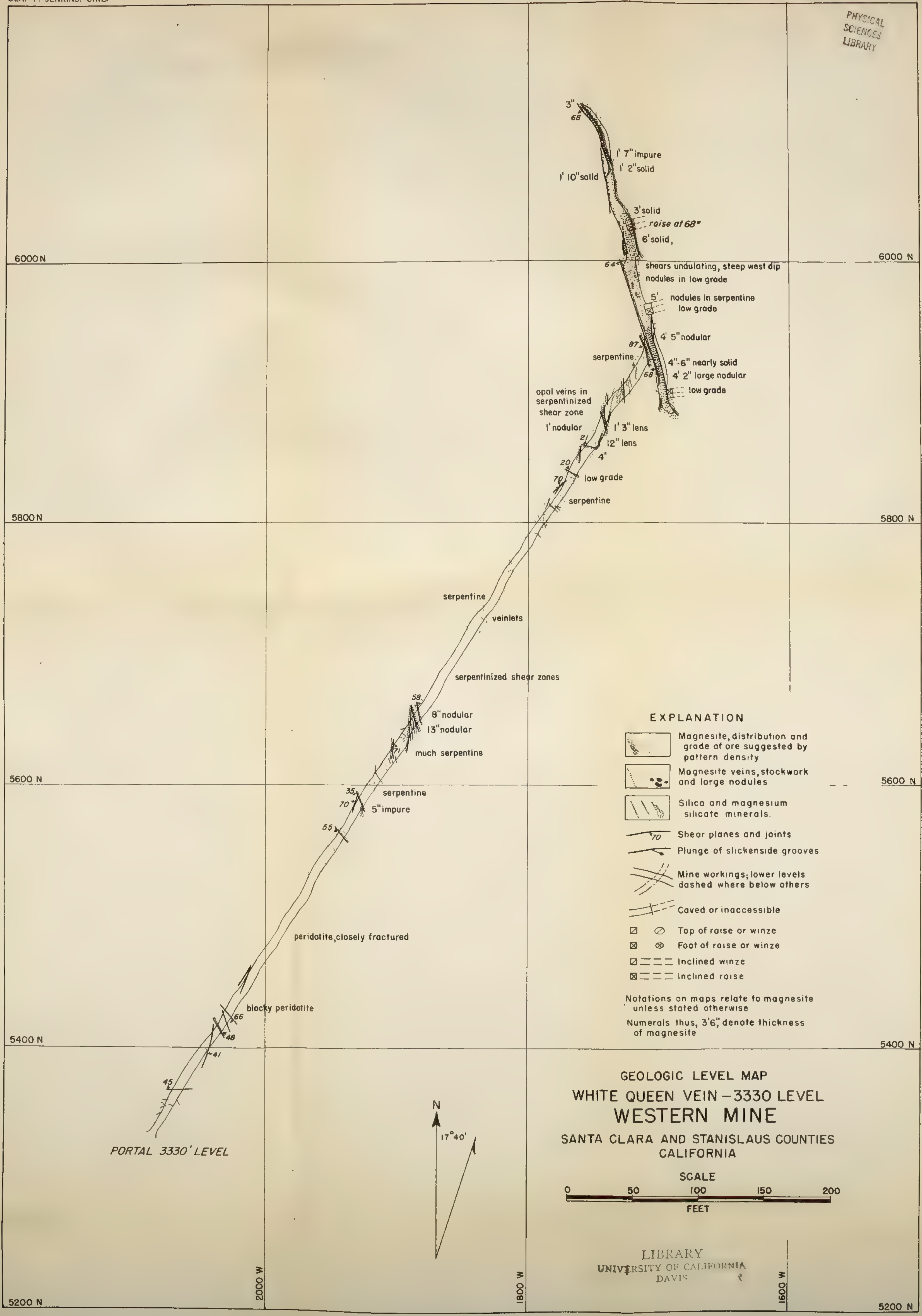
6000 N
5800 N
5600 N
5400 N
5200 N
2000 W
1800 W
1600 W
3"
68
1' 7" impure
1' 2" solid
1' 10" solid
3' solid
raise at 68°
6' solid,
64
shears undulating, steep west dip
nodules in low grade
5'
nodules in serpentine
low grade
4' 5" nodular
87
serpentine
4"-6" nearly solid
68
4' 2" large nodular
low grade
opal veins in
serpentinized
shear zone
1' nodular
1' 3" lens
21
12" lens
4"
20
70
low grade
serpentine
serpentine
veinlets
serpentinized shear zones
58
8" nodular
13" nodular
71
much serpentine
35
70
serpentine
5" impure
55
peridotite, closely fractured
blocky peridotite
66
48
41
45
PORTAL 3330' LEVEL
N
17°40'
EXPLANATION
Magnesite, distribution and grade of ore suggested by pattern density
Magnesite veins, stockwork and large nodules
Silica and magnesium silicate minerals.
70
Shear planes and joints
Plunge of slickenside grooves
Mine workings; lower levels dashed where below others
Caved or inaccessible
Top of raise or winze
Foot of raise or winze
Inclined winze
Inclined raise
Notations on maps relate to magnesite unless stated otherwise
Numerals thus, 3'6", denote thickness of magnesite
SCALE
0
50
100
150
200
FEET

GEOLOGIC LEVEL MAP
WHITE QUEEN VEIN — 3330 LEVEL
WESTERN MINE
SANTA CLARA AND STANISLAUS COUNTIES
CALIFORNIA

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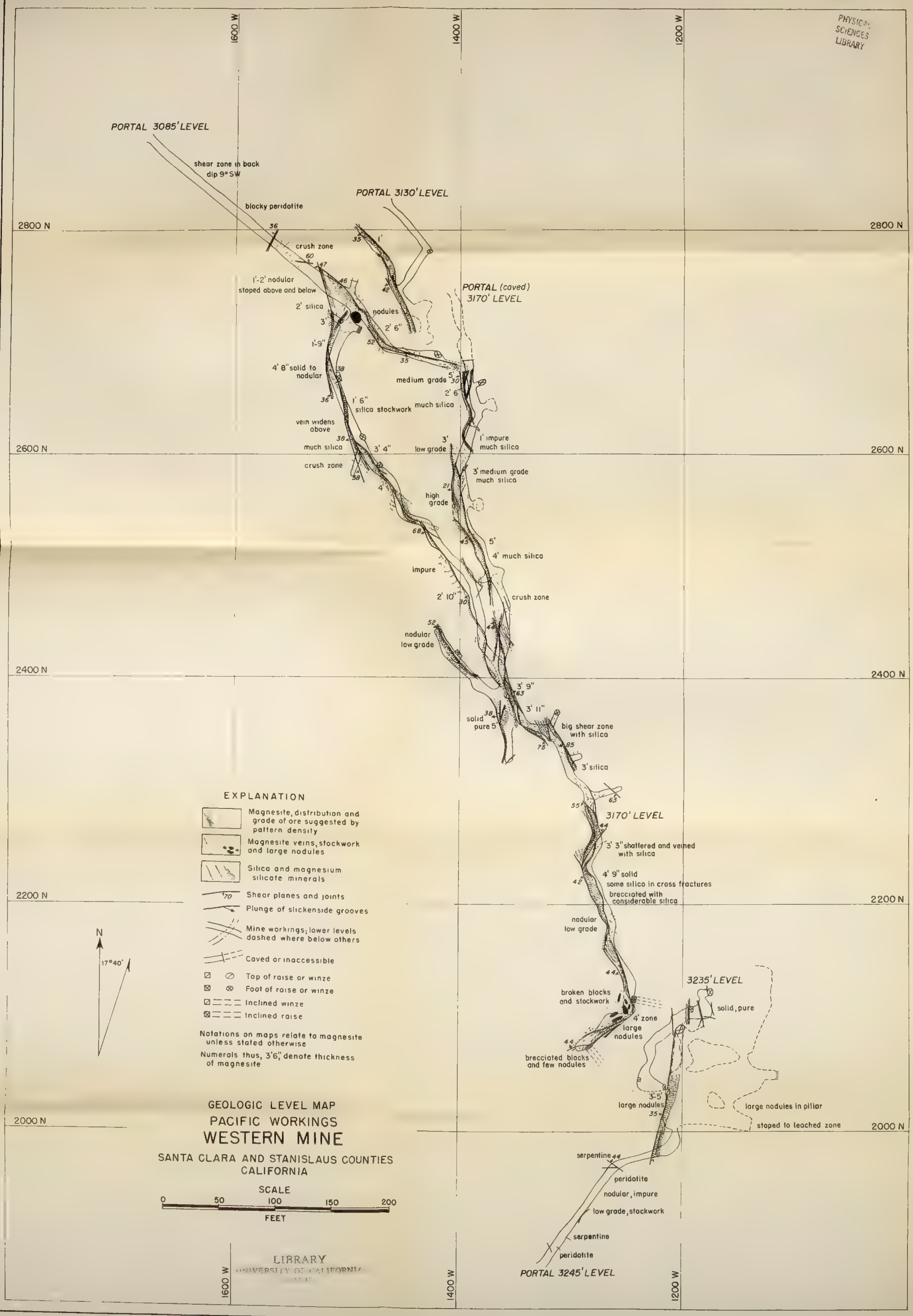
1600 W
1400 W
1200 W
2800 N
2600 N
2400 N
2200 N
2000 N
PORTAL 3085' LEVEL
shear zone in back dip 9° SW
blocky peridotite
PORTAL 3130' LEVEL
36
crush zone
60
47
1'-2' nodular stoped above and below
46
42
35
1'
PORTAL (caved) 3170' LEVEL
2' silica
3"
nodules
2' 6"
1'-9"
52
35
4' 8" solid to nodular
38
medium grade
5'
30
2' 6"
36
1' 6" silica stockwork
much silica
vein widens above
38
3'
1' impure much silica
much silica
3' 4"
low grade
crush zone
58
3' medium grade much silica
4'
21
high grade
68
45
5'
4' much silica
impure
2' 10"
30
crush zone
52
nodular low grade
3' 9"
63
solid pure 5'
38
3' 11"
big shear zone with silica
76
85
3' silica
55
63
3170' LEVEL
44
3' 3" shattered and veined with silica
42
4' 9" solid some silica in cross fractures
brecciated with considerable silica
nodular low grade
44
3235' LEVEL
broken blocks and stockwork
solid, pure
4' zone large nodules
44
brecciated blocks and few nodules
3-5' large nodules
large nodules in pillar
35
stoped to leached zone
serpentine
44
peridotite
nodular, impure
low grade, stockwork
serpentine
peridotite
PORTAL 3245' LEVEL
N
17°40'
EXPLANATION
Magnesite, distribution and grade of ore suggested by pattern density
Magnesite veins, stockwork and large nodules
Silica and magnesium silicate minerals
70
Shear planes and joints
Plunge of slickenside grooves
Mine workings; lower levels dashed where below others
Caved or inaccessible
Top of raise or winze
Foot of raise or winze
Inclined winze
Inclined raise
Notations on maps relate to magnesite unless stated otherwise
Numerals thus, 3'6", denote thickness of magnesite
SCALE
0
50
100
150
200
FEET

GEOLOGIC LEVEL MAP
PACIFIC WORKINGS
WESTERN MINE
SANTA CLARA AND STANISLAUS COUNTIES
CALIFORNIA

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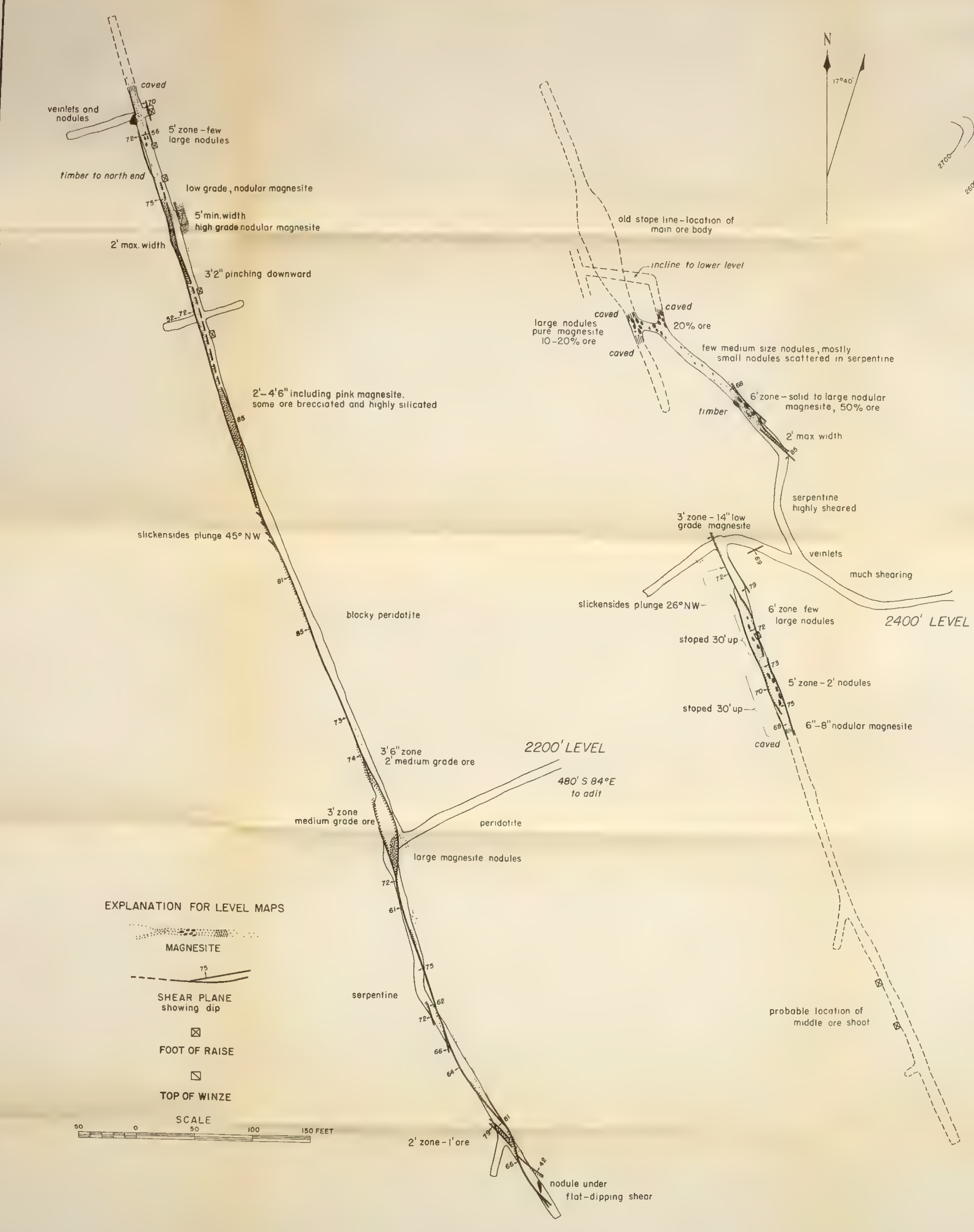
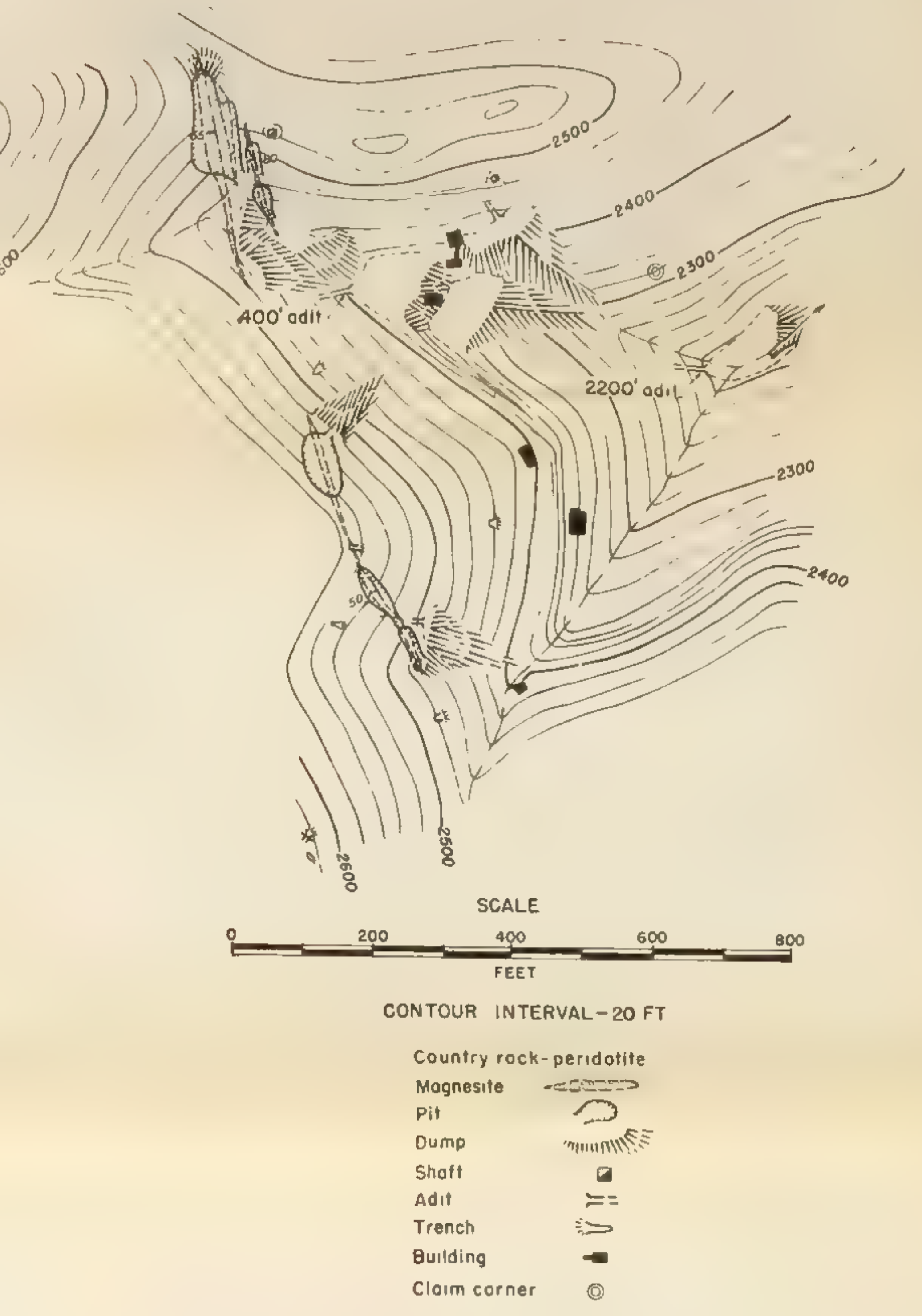
JOURNAL
VOLUME 46 PLATE 49


caved
veinlets and nodules
70
56
72
5' zone - few large nodules
timber to north end
low grade, nodular magnesite
75
5' min. width
high grade nodular magnesite
2' max. width
3'2" pinching downward
52
72
2'-4'6" including pink magnesite. some ore brecciated and highly silicated
85
slickensides plunge 45° NW
81
blocky peridotite
85
73
74
3'6" zone
2' medium grade ore
2200' LEVEL
480' S 84°E
to adit
3' zone
medium grade ore
peridotite
large magnesite nodules
72
61
75
serpentine
62
72
66
64
81
79
2' zone - 1' ore
66
42
nodule under
flat-dipping shear
EXPLANATION FOR LEVEL MAPS
MAGNESITE
75
SHEAR PLANE
showing dip
FOOT OF RAISE
TOP OF WINZE
SCALE
50
0
50
100
150 FEET
N
17°40'
old stope line - location of main ore body
incline to lower level
caved
caved
large nodules
pure magnesite
10-20% ore
caved
20% ore
few medium size nodules, mostly
small nodules scattered in serpentine
68
6' zone - solid to large nodular magnesite, 50% ore
timber
2' max width
85
serpentine
highly sheared
3' zone - 14" low grade magnesite
69
veinlets
much shearing
72
79
slickensides plunge 26° NW
6' zone few
large nodules
2400' LEVEL
72
stoped 30' up
73
5' zone - 2' nodules
70
75
stoped 30' up
69
6"-8" nodular magnesite
caved
probable location of
middle ore shoot


2700
2600
2500
2400
2300
400' adit
2200' adit
2300
2400
50
2600
2500
SCALE
0
200
400
600
800
FEET
CONTOUR INTERVAL - 20 FT
Country rock - peridotite
Magnesite
Pit
Dump
Shaft
Adit
Trench
Building
Claim corner

GEOLOGIC and TOPOGRAPHIC MAPS
RED MOUNTAIN MAGNESITE MINE
(PATTERSON MINE)
STANISLAUS COUNTY, CALIFORNIA

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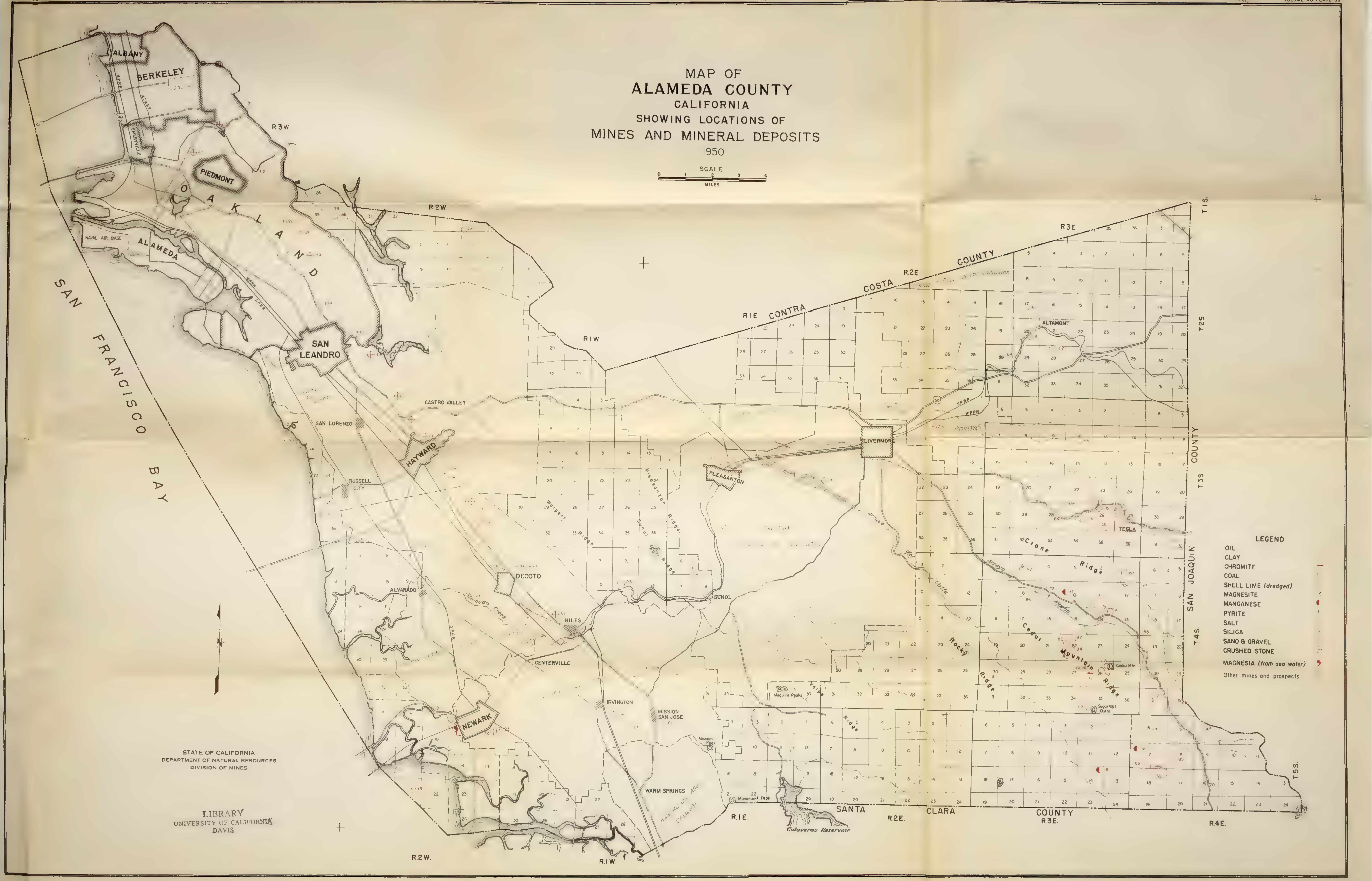

MAP OF
ALAMEDA COUNTY
CALIFORNIA
SHOWING LOCATIONS OF
MINES AND MINERAL DEPOSITS
1950

SCALE
0 1 2 3 4
MILES
LEGEND
OIL
CLAY
CHROMITE
COAL
SHELL LIME (dredged)
MAGNESITE
MANGANESE
PYRITE
SALT
SILICA
SAND & GRAVEL
CRUSHED STONE
MAGNESIA (from sea water)
Other mines and prospects
ALBANY
BERKELEY
EMERYVILLE
PIEDMONT
OAKLAND
ALAMEDA
NAVAL AIR BASE
SAN LEANDRO
SAN FRANCISCO BAY
CASTRO VALLEY
SAN LORENZO
HAYWARD
RUSSELL CITY
DECOTO
ALVARADO
Alameda Creek
NILES
CENTERVILLE
IRVINGTON
MISSION SAN JOSE
Mission Peak
WARM SPRINGS
NEWARK
SUNOL
PLEASANTON
LIVERMORE
ALTAMONT
TESLA
Walpert Ridge
Pleasanton Ridge
Sunol Ridge
Arroyo del Valle
Arroyo Mocho
Crane Ridge
Cedar Mountain Ridge
Rocky Ridge
Vallejo Ridge
Maguire Peaks
Monument Peak
Sugarloaf Butte
Cedar Mtn
Calaveras Reservoir
CONTRA COSTA COUNTY
SAN JOAQUIN COUNTY
SANTA CLARA COUNTY
R3W
R2W
R1W
R1E
R2E
R3E
R4E
T1S
T2S
T3S
T4S
T5S
SPRR
WPRR
AT&SF

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CALIFORNIA JOURNAL OF MINES AND GEOLOGY

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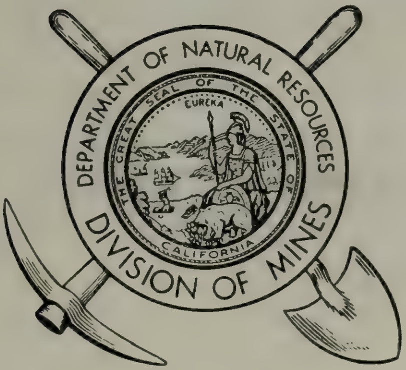
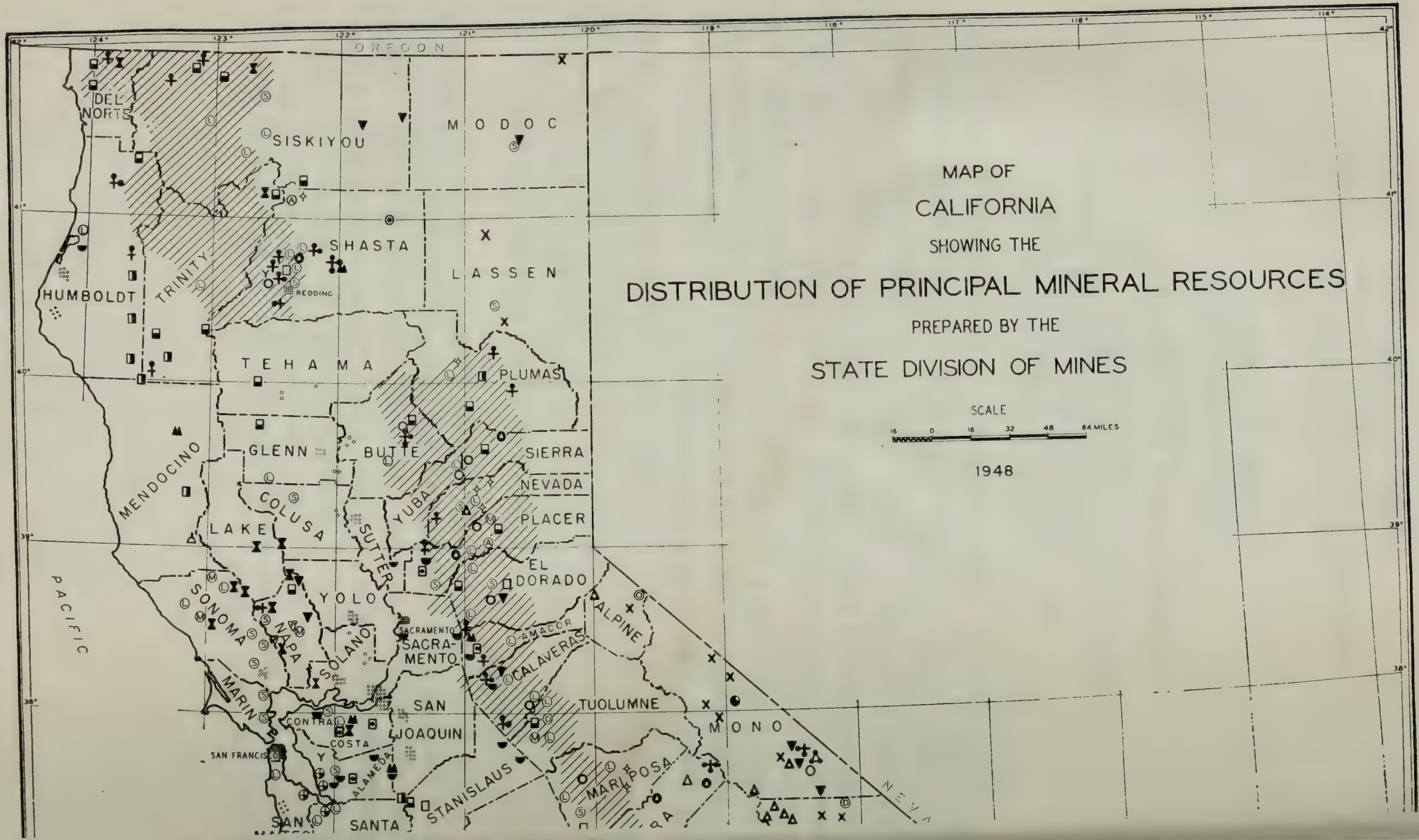


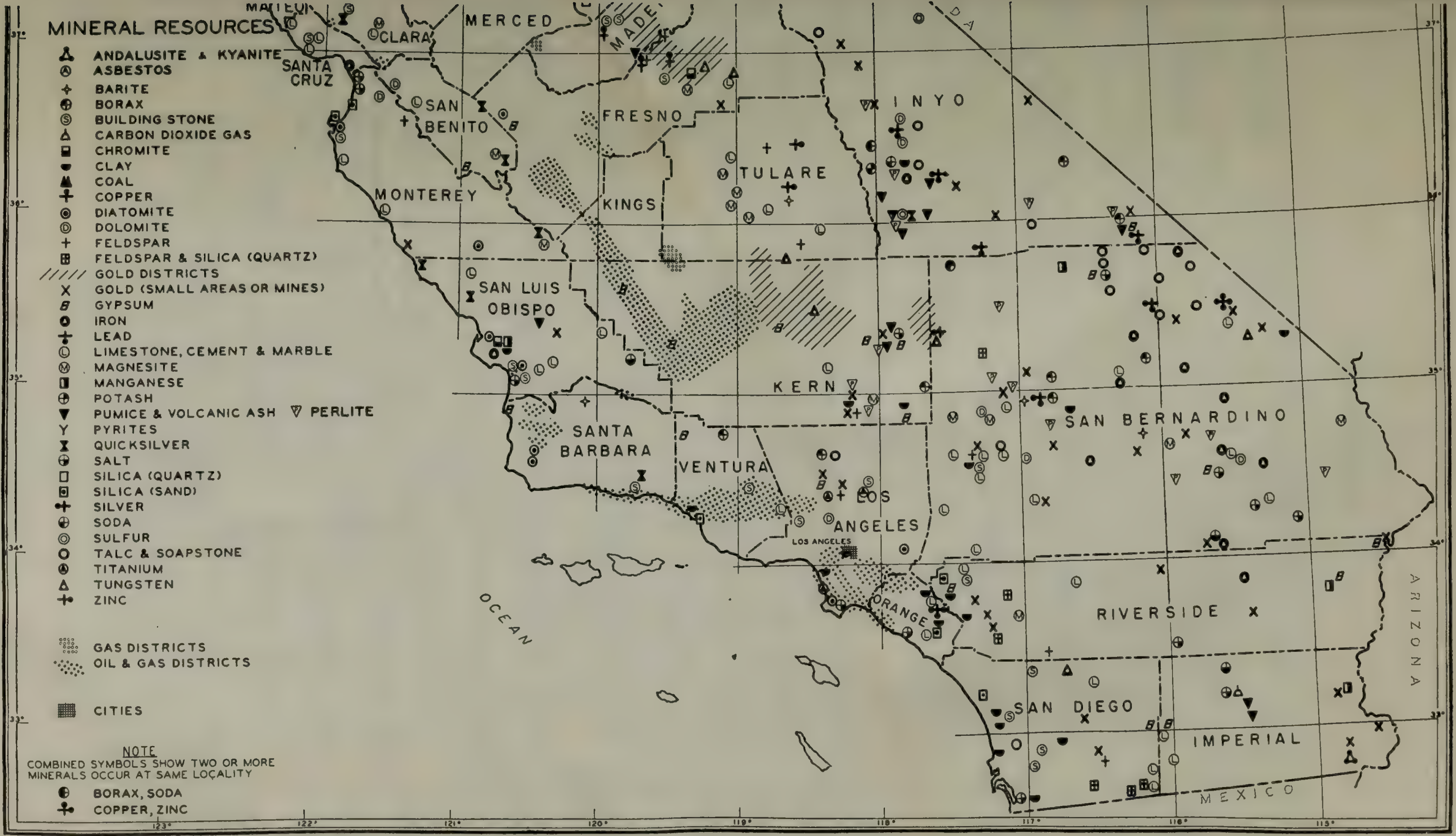


MAP OF
CALIFORNIA
SHOWING THE
DISTRIBUTION OF PRINCIPAL MINERAL RESOURCES
PREPARED BY THE
STATE DIVISION OF MINES

SCALE

1948

16
0
16
32
48
64 MILES
OREGON
NEVADA
PACIFIC
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
REDDING
LASSEN
TEHAMA
PLUMAS
GLENN
BUTTE
SIERRA
NEVADA
MENDOCINO
COLUSA
YUBA
PLACER
LAKE
SUTTER
EL DORADO
SONOMA
YOLO
NAPA
ALPINE
SACRAMENTO
SACRAMENTO
AMADOR
CALAVERAS
SOLANO
MARIN
TUOLUMNE
SAN JOAQUIN
CONTRA COSTA
MONO
SAN FRANCISCO
ALAMEDA
STANISLAUS
MARIPOSA
SAN MATEO
SANTA
124°
123°
122°
121°
120°
119°
118°
117°
116°
115°
114°
42°
41°
40°
39°
38°


MINERAL RESOURCES
ANDALUSITE & KYANITE
ASBESTOS
BARITE
BORAX
BUILDING STONE
CARBON DIOXIDE GAS
CHROMITE
CLAY
COAL
COPPER
DIATOMITE
DOLOMITE
FELDSPAR
FELDSPAR & SILICA (QUARTZ)
GOLD DISTRICTS
GOLD (SMALL AREAS OR MINES)
GYPSUM
IRON
LEAD
LIMESTONE, CEMENT & MARBLE
MAGNESITE
MANGANESE
POTASH
PUMICE & VOLCANIC ASH
PERLITE
PYRITES
QUICKSILVER
SALT
SILICA (QUARTZ)
SILICA (SAND)
SILVER
SODA
SULFUR
TALC & SOAPSTONE
TITANIUM
TUNGSTEN
ZINC
GAS DISTRICTS
OIL & GAS DISTRICTS
CITIES
NOTE
COMBINED SYMBOLS SHOW TWO OR MORE MINERALS OCCUR AT SAME LOCALITY
BORAX, SODA
COPPER, ZINC
SANTA CRUZ
CLARA
MERCED
MADERA
SAN BENITO
FRESNO
MONTEREY
KINGS
TULARE
INYO
SAN LUIS OBISPO
KERN
SANTA BARBARA
VENTURA
LOS ANGELES
SAN BERNARDINO
ORANGE
RIVERSIDE
SAN DIEGO
IMPERIAL
ARIZONA
MEXICO
OCEAN
37°
36°
35°
34°
33°
123°
122°
121°
120°
119°
118°
117°
116°
115°

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NEEDLES MAGNESITE DEPOSIT, SAN BERNARDINO COUNTY, CALIFORNIA *

By Charles J. Vitaliano **

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ABSTRACT

Two deposits of bedded or sedimentary magnesite occur on the west side of the Sacramento Mountains, 14 miles southwest of Needles, San Bernardino County, California. In the Needles deposit, which is the better exposed of the two, the magnesite occurs in a shallow basin as a thin lens 600 feet wide and 2,400 feet long with a maximum thickness of 12 feet. The basement rocks, gneisses, and granites are believed to be of pre-Cambrian age. They are overlain by volcanic tuffs, breccias, and sedimentary rocks, all probably of Tertiary age. The sedimentary rocks enclose the magnesite layer. The magnesite is highly contorted, considerably faulted, and discon-

---

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** Geologist, U. S. Department of the Interior, Geological Survey.

tinuous within the lens-shaped area. Compared with similar deposits, the Needles magnesite is unusually pure. The CaO content ranges from 0.48 percent to 8.5 percent, SiO_2 may reach 6.0 percent, and the combined Al_2O_3 and Fe_2O_3 is generally less than 1.0 percent. Reserves in the Needles deposit are estimated at 117,000 tons of indicated ore and 410,000 tons of inferred ore.

The nearby Capitan deposit, only slightly exposed in 1944, consists of two parallel bands of magnesite, each about 8 feet thick, and associated material.

INTRODUCTION

The Needles area is on the western slope of the Colorado River Valley in the southwestern part of the Great Basin. The Sacramento Mountains in which the magnesite deposits occur, one of the major mountain ranges in the Needles area, are a bow-shaped range trending north, adjoined by the Mohave Mountains on the southeast and the Dead Mountains on the north. The mountain front on the east intersects a series of coalescing fans which slope at a uniform rate down to the Colorado River. On the west a remarkably straight, steep edge truncates the main range and separates it from the adjacent pediment and low-lying hills which occur to the west.

Two deposits of bedded or sedimentary magnesite are known in the Needles area, San Bernardino County, California (fig. 1). The Needles deposit is covered by four placer claims: White Moon nos. 1, 2, 3, and 4, in the S½ sec. 15 and in the N½ sec. 22, T. 8 N., R. 21 E., S. B. A desert road, which was in very poor condition during 1943, leads directly from the city of Needles to the deposit. This road is on a terrace on the southeast bank of Eagle Creek for a distance of 7 miles and then on the loose

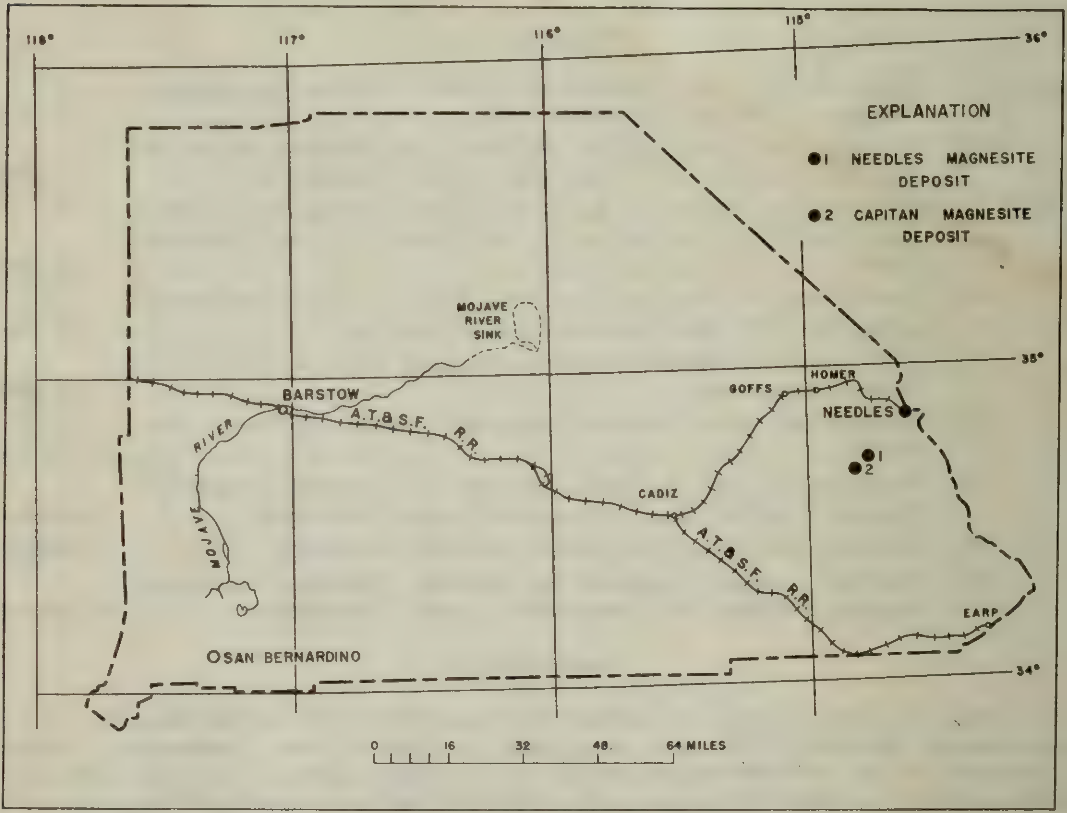
118°
117°
116°
115°
36°
35°
34°
EXPLANATION
●1 NEEDLES MAGNESITE DEPOSIT
●2 CAPITAN MAGNESITE DEPOSIT
MOJAVE RIVER SINK
BARSTOW
A.T.& S.F. R.R.
RIVER
MOJAVE
GOFFS
HOMER
NEEDLES
1
2
CADIZ
A.T.& S.F. R.R.
EARP
SAN BERNARDINO
0
16
32
48
64 MILES

FIGURE 1. Index map of San Bernardino County, California, showing location of magnesite in the Needles area.

gravels of the wash for the remaining 7 miles. A longer, though less arduous route follows U. S. Highway 66 for 20 miles over South Pass from the city of Needles to the Metropolitan Water Supply power line, then south along the power line road for 9 miles to the Beacon Tower road, and southeast along Beacon Tower road for 5 miles, partly in loose sand, to the property, a total distance of 34 miles. The Capitan magnesite deposit is on the pediment at the base of the western foothills of the Sacramento Mountains. The deposit is in the southwestern part of T. 8 N., R. 21 E., about 15 miles southwest of the Homer siding on the Atchison, Topeka and Santa Fe Railroad. The road from Homer siding follows the Metropolitan Water Supply power line southeast to the Beacon Tower road. A turn-off 2 miles along the Beacon Tower road from the junction leads directly to the property.

History and Development

The only work which had been done on the magnesite in the Needles area prior to September 23, 1935, consisted of three small prospect pits on the Needles deposit. At that time the California Chemical Co., now the Westvaco Chemical Division, Food Machinery and Chemical Corp., began an exploration program, during which sixty trenches were opened, and four diamond drill holes, totalling 157 feet, were drilled on the Needles deposit. All of the exploratory work was limited to an area of 60 acres which showed positive indications of magnesite. No further work was done on the Needles magnesite deposit until March 1943, when the property was leased to Mr. J. Lex Brown of San Bernardino, California, and associates. Machinery was brought to the property, and it was planned to mine the ore with a small power shovel. By April 1943, a small quarry had been opened, and one car of ore was shipped, after which operations are reported to have ceased.

When the Capitan deposit was first visited in March 1943, it contained only two prospect shafts, in both of which magnesite was exposed. An exploration program was in progress at the time, however, and when the property was revisited in July 1944, two large pits had been excavated exposing the magnesite.

Previous Work

The first geologic mapping of the Needles deposit was done in September 1935, by Gerald M. Kirwan, geologist for the California Chemical Co., during its magnesite exploration program. In December 1941, the property was examined and mapped by L. Fillaseta and H. Nye for Basic Magnesium, Inc., of Las Vegas, Nevada. In March 1942, J. A. Vandegrift of Los Angeles, California, made a sketch map of the deposit and made chemical analyses of 27 selected samples for Defense Plant Corporation. None of the above reports were published, as all were of a confidential nature.

The Needles deposit was briefly visited for the U. S. Geological Survey by Eugene Callaghan, John Loufborrow, and the writer, accompanied by J. A. Vandegrift, in October 1942.

Field Work

During February and March 1943, the writer and Alfred J. Bodenlos spent 5 weeks in the area mapping the Needles deposit on a scale of

1 : 2,400 and examining the Capitan prospect. Additional trenching was done, and samples were taken and analyzed. When the writer revisited the area in July 1944, with Ian Campbell of the Division of Geological Sciences, California Institute of Technology, and J. A. Vandegrift, a small quarry had been opened in the magnesite at the Needles deposit, and two pits had been excavated on the Capitan deposit. A sketch map of the main pit on the Capitan deposit is shown in figure 2.

Table 1. Stratigraphic column of the Tertiary rocks at the Needles magnesite deposit, sec. 22, T. 8 N., R. 21 E., San Bernardino County, California.

Thickness (feet)	Field name	Description
Unknown..	Volcanics (agglomerate and latitic flows)	Agglomerate, buff to brownish matrix containing fragments of all volcanic and sedimentary rocks in area. Fragments up to 2 inches in diameter. Cavernous weathering surface. Latitic flows, massive flow rock, brick red, feldspar phenocrysts set in very fine-grained groundmass.
10+......	Cherty dolomite	Light- to dark-gray to grayish-blue, fine- to medium-grained dolomite. Weathered surface is rough and pitted with rust-stained chert nodules and lenses commonly 10 feet long and 1 foot wide. The upper contact of the cherty dolomite with the overlying volcanics was not found in the mapped area.
80+......	Dolomite, tuff, shale, and magnesite-bearing horizon	Dolomite, minimum thickness 12.6 feet. The lower 9.0 feet is thin-bedded, creamy-white dolomite. The upper 3.6 feet is massive dolomite, weathering into blocks as much as 2.5 feet in diameter. The upper part locally contains thin shale partings. Shales, interbedded dolomites, and tuffs (thickness 9 feet). Lower 2.5 feet of this member, light- to dark-gray, buff to brown fissile shale and interbedded thinly laminated light-gray to white dolomite. The shale portion weathers to a soft claylike consistency. Middle part of this member is 5.1 feet of light-gray tuff with dolomite fragments. Upper 1.6 feet of this member is thin-bedded, dark-brown shale with irregular fractures. A few thin zones of clayey material resembling fault gouge. At the top is 0.5 feet of dolomite. Dolomite, grayish white on fresh surface, weathering to white upon exposure. Beds range up to 0.2 inch in thickness separated by thin shaly partings. Thickness 5.0 feet. Magnesite, chocolate brown on freshly broken surface, drying to white, somewhat crumbly mass upon exposure. Fine-grained and thin-bedded, beds ranging from 0.5 inch to 6 inches, with bedding surface frequently slickensided. Commonly the beds are intricately folded. Shaly partings between magnesite beds up to 2 inches thick. About 10 inches of thin-bedded shale is found in places at top of magnesite horizon. **Dolomite.**—Thin-bedded, rusty-brown, with interbedded cherty layers ranging up to 1/10 inch thick. Chert layers are continuous and of uniform thickness. Total thickness of this horizon 4 feet plus. **Shale.**—Thin-bedded, fissile, white to grayish white. Upon exposure, the shale dries out and crumbles, and as a result areas underlain by shale are soft under foot and form depressions. The shales and the overlying magnesite are intricately folded and faulted.
30+......	Volcanic tuffs and flows	(Andesite tuff.) Bedded pyroclastics and flows, predominantly brownish-yellow with greenish, whitish, and red varieties. Beds 1 foot to 3 feet thick, porous, highly jointed, with caliche deposited along joints; feldspar, biotite, and magnetite grains in a brownish-yellow, glassy groundmass. Interbedded flow layers; euhedral feldspar and hornblende grains in a banded glassy groundmass.
7+......	Dolomitic limestone	(Occurs just outside area mapped.) Fine-grained, thin-bedded, grayish-white dolomitic limestone. (Exact thickness unknown owing to incomplete exposure.) Exposed only on crest of anticline just outside magnesite-bearing area, below and in contact with andesite tuff.

Acknowledgments

The writer wishes to express his thanks to the Westvaco Chemical Division, Food Machinery and Chemical Corp., for making available the maps and chemical analyses in Gerald M. Kirwan's report on the Needles deposit and to Mr. J. A. Vandegrift for making available a report containing chemical analyses of the magnesite. To Eugene Callaghan the author is indebted for guidance and helpful criticism in the field and in the preparation of the report. Grateful acknowledgment is accorded to A. J. Bodenlos, whose very able assistance in the field and in the drafting of the map of the Needles deposit helped considerably in the final preparation of this report.

GEOLOGY

The major geologic units in the Needles area are the pre-Cambrian metamorphic rocks, the Tertiary volcanic and associated sedimentary rocks, and the Quaternary sediments.

Pre-Cambrian Rocks

The pre-Cambrian rocks, greenish to gray gneisses injected with pink to gray granite, are exposed in the Sacramento Range and in the bottoms of the washes along the roads leading into the mountains. The injected rock is coarsely crystalline, in places essentially pegmatitic. Close folding of foliation bands is common in the gneiss along the road leading up Eagle Wash.

Sequence of Tertiary Formations at the Needles Deposit

The Tertiary rocks in the Needles magnesite area are volcanic tuffs and andesitic flows associated with a series of sedimentary rocks in which the magnesite bed occurs.

The stratigraphic column at the Needles magnesite deposit consists of a series of volcanic tuffs and flows, shales, dolomites, limestones, magnesite, and cherty dolomite. Because of the intense disturbance of the sediments, the measurement of a true stratigraphic section is difficult. Trench no. GS (pl. 62) was excavated by the U. S. Geological Survey across the strike of the sedimentary rocks in an area where the rocks appeared to be relatively undisturbed. The section from the top of the andesite tuff upward to the cherty dolomite was exposed (see table 1). A few seams of fault gouge were uncovered, but upon checking, these proved to be very local and due to small-scale movements. The thickness of the andesite tuff and flows was measured just beyond the southeastern limit of the mapped area, where the volcanics are in contact with the underlying dolomitic limestone (pl. 59). The thickness of the exposed part of the cherty dolomite was measured within the mapped area in the southeastern part of the section. The full thickness of this member is unknown, because nowhere in the district is the cherty dolomite found in contact with the overlying younger volcanic rocks.

Although no direct evidence of the age of the sedimentary rocks was found, they are classified here as Tertiary because of their association with the tuffs and flows which are similar to Tertiary[1] volcanic tuffs and flows in the Chemehuevi Mountains and Mojave Mountains in San Bernardino County, California, and in the Black Mountains, Mohave County, Arizona, just across the Colorado River.

---

[1] Schrader, F. C., Mineral deposits of the Cerbat Range, Black Mountains, and Grand Wash Cliffs, Mohave County, Arizona: U. S. Geol. Survey Bull. 397, p. 37, 1909.

Newberry [2] described briefly the geology of the Chemehuevi Valley, the Mohave Mountains, the Mohave Valley, and particularly the western slope of the Colorado River Valley leading up to the mountains (the present Sacramento Mountains), and Dead Mountain. The volcanic tuffs and flows and the associated sedimentary rocks were classified as of Tertiary age.

Lee [3] and Schrader [4] have described the geology of Mohave County, Arizona. Schrader's map shows that the Sacramento Mountains and the surrounding region west of the Colorado River are underlain by ''undifferentiated, principally pre-Cambrian, granitoid series with local areas of Tertiary volcanics (andesites, trachytes, rhyolites, etc.) and some Quaternary (?) basalts.''

Quaternary Deposits

Sediments composed of coarse pebbles of sedimentary and volcanic rocks are found in the present washes, especially in the vicinity of the Needles magnesite deposit. These sediments are mainly unconsolidated, but some of the gravels and conglomerates within the magnesite-bearing area are cemented. Generally the sediments are flat lying and unfaulted except in several localities, especially east of the Needles magnesite deposits, where the sediments have been tilted as much as 10°. The loose gravels and the fine alluvium in the present washes constitute the latest deposits.

STRUCTURE OF THE NEEDLES DEPOSIT

The Needles magnesite deposit is in a physiographic basin rimmed by hills on three sides and open on the fourth side. The sedimentary rocks, which include limestones, dolomites, cherty dolomite and shale, as well as magnesite, dip outward and beneath the younger volcanic rocks at the periphery of the amphitheater. Thus the geological structure of the magnesite area is a dome. Superimposed upon the major dome structure is a series of minor folds in the sedimentary and interbedded volcanic rocks. In general the axes of the minor folds are parallel and trend about N. 10° to 20° W. Outcrops of the more resistant cherty dolomite beds form zigzag ridges on the limbs of the folds. On the map of the magnesite deposit, the distribution of the thin-bedded dolomite, shale, and magnesite horizon indicates the pattern of the folds in the sedimentary rocks (pls. 63 and 64). A few cross-folds occur, and in these the axial trend is eastward.

A series of major normal faults and innumerable minor normal faults cut the sedimentary rocks in the mapped area. The major faults are parallel and trend north, making an angle of 25° with the axes of the northwest-trending folds. There are five major faults in the area, but only two of them have affected the magnesite horizon as it now is exposed. In the southeastern part of the mapped area three parallel faults bring the lower andesite tuff into contact with the capping of cherty dolomite.

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[2] Newberry, J. S., in Lt. J. C. Ives' Report of the Colorado River of the West, pt. 3, pp. 29-54, 1861.

[3] Lee, W. S., Geologic reconnaissance of a part of western Arizona: U. S. Geol. Survey Bull. 352, 1908.

[4] Schrader, F. C., op. cit., pl. 1.

The throw on all faults is small, probably at no place exceeding 50 to 75 feet.

One reverse fault of small throw was mapped in the extreme northwest part of the area, and another was mapped along the southern part of the northeastern contact between the pre-Cambrian granite and the sedimentary rocks. The tilting of the gravels and the displacement of the alluvium along some of the faults indicate recent movement along the faults in the area.

MINERAL DEPOSITS

Needles Deposit

The magnesite in the needles area occurs as thin-bedded, very fine-grained, white rock. Thin shaly partings up to 2 inches thick separate the individual magnesite layers (pl. 60). In contrast to the magnesite found in altered serpentine deposits of western United States, the magnesite from the Needles area is not hard and lacks conchoidal fracture. Similar soft sedimentary magnesite has been described from Bissell, Kern County, and Afton, San Bernardino County, California.[5] The Needles magnesite has a rudimentary subconchoidal fracture on which are slickensided surfaces as a result of local gliding. The magnesite is chocolate brown on freshly broken surfaces, but upon exposure changes to white and becomes powdery.

The magnesite in the Needles deposit is limited to a single lens-shaped horizon, thinning out toward the edge. The lateral extent of the lens may be small, as shown in cross sections GG′, HH′, or II′, or the lens may thin out gradually, as in sections CC′, and DD′. The incompetence of the magnesite is reflected in the severe folding of the beds and the pinching out of the magnesite in many places (pl. 65). Probably most of the variation in thickness of the magnesite horizon is due to pinching. In some places intense folding actually has resulted in breaking and thrusting the magnesite so that magnesite ore abuts against dolomite (see pl. 65, trench 11), but elsewhere the thickness of the magnesite is increased by tight folding and overturning (see pl. 65, trenches 30 and 31, and pl. 61).

The magnesite outcrops are limited to an area 600 feet wide and 2,400 feet long, elongated northwest. In this area folding of the magnesite and the adjacent sediments may carry the magnesite to depths as great as 100 feet (see pl. 64, cross sections DD′ and II′). The pattern of the folds in the sedimentary rocks is indicated by the zigzag outcrop of the white magnesite beds in the northern part of the mapped area. In addition, the magnesite in the central part of the ore-bearing area has been displaced by normal faulting. The maximum throw on any of the faults is generally less than 75 feet.

The main impurities in the magnesite are CaO, SiO_2, and Al_2O_3 and Fe_2O_3. The Al_2O_3 and Fe_2O_3 content is generally low as indicated in all the chemical analyses (see tables 2, 4, 5, 6). In all the chemical analyses made by the U. S. Geological Survey, the Al_2O_3 and Fe_2O_3 content was determined collectively as R_2O_3, which, with one single exception, did not exceed 1.9 percent and in most samples did not reach 1 percent. It was found that the SiO_2 content generally depended upon where the sample had been collected. Within the magnesite horizon the SiO_2 content was generally less than 10 percent and in many samples was less than 5 percent. Samples with the SiO_2 content in excess of 10 percent were either shaly or clay-like in appearance in the field and generally were not part of the magnesite horizon. SiO_2 was frequently reported as insoluble.

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[5] Gale, H. S., Late developments of magnesite deposits in California and Nevada: U. S. Geol. Survey Bull. 540, p. 515, 1912.
Bradley, W. W., Magnesite in California: California Min. Bur. Bull. 79, pp. 49, 75, 1925.
Rubey, W. W., and Callaghan, Eugene, in Hewett, D. F., et al., Mineral resources of the region around Boulder Dam: U. S. Geol. Survey Bull. 871, pp. 114-118, 1936.

The CaO content in the analyzed samples ranged from 0.30 percent to more than 28 percent. It is believed that CaO is combined with MgO and CO_2 to form dolomite, the carbonate impurity in the magnesite horizon. Excess MgO over the amount required to make up the carbonate minerals magnesite and dolomite is probably combined with SiO_2 and H_2O to form a hydrous magnesium silicate.

Six complete analyses made from samples taken in trench GS excavated by the U. S. Geological Survey, are given in table 2. Two of these are combined samples made in order to determine whether or not a given thickness of sediments containing some obvious layers of dolomite could be mined and treated as a unit.

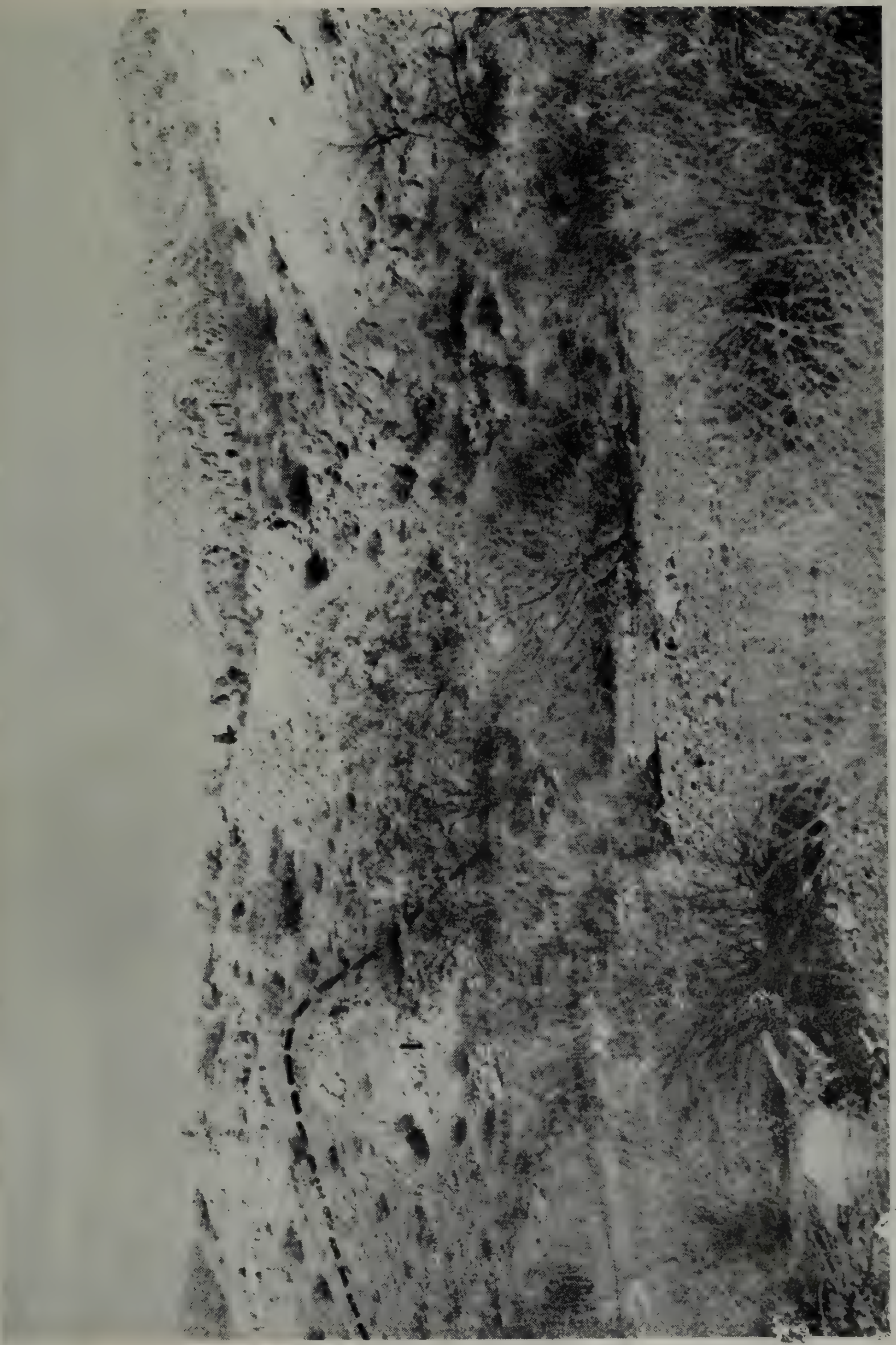
Table 2. Chemical analyses of samples taken from U. S. Geological Survey trench, Needles magnesite deposit.

Sample	GS-h	GS-i	GS-r	GS-s	GS-1	GS-2
SiO_2	12.97	28.65	10.09	5.27	5.82	14.31
Fe_2O_3	.24	.32	.08	.34	.16	.22
Al_2O_3	.40	1.51	.69	.26	.60	.59
Cr_2O_3 *	------	------	------	------	------	------
TiO_2 *	------	------	------	------	------	------
CaO	24.06	13.99	16.86	13.18	17.02	23.17
MgO	22.94	25.70	30.02	34.52	29.01	23.27
CO_2	34.47	22.50	39.22	45.19	41.69	35.28
H_2O	2.01	7.35	3.13	1.30	5.93	2.97

GS-h: 0.11 feet......whitish, thin-bedded dolomite, V. North, analyst.
GS-i: 1.95 feet......soft, whitish, thin-bedded shale, V. North, analyst.
GS-r: .83 feet......white, thin-bedded, dolomitic magnesite, V. North, analyst.
GS-s: 4.90 feet......whitish, thin-bedded, dolomitic magnesite, V. North, analyst.
GS-1: 5.50 feet......combined sample white magnesite with thin dolomite seams and with thin layer (2 feet) of impure magnesite, V. North, analyst.
GS-2: 4.70 feet......combined sample buff, gray, gray-brown to brown, impure dolomite with argillaceous layers, V. North, analyst.

* Cr_2O_3 and TiO_2 were not found, although specific tests were made.

The magnesite in the Needles deposit is remarkable for its low content of insoluble material and of R_2O_3. The chemical analyses of specimens taken by both Westvaco Chlorine Products Corp. and the U. S. Geological Survey show that the insoluble content for specimens high in $MgCO_3$ is almost invariably less than 5 percent and generally less than 2.5 percent. In comparison with sedimentary magnesite from other deposits in California and Nevada, the insoluble content of the Needles deposit is very low. Published analyses of the samples from the Bissell magnesite deposit



Photograph southeast of mapped area showing contact (dashed line) between volcanics on top and lower dolomitic limestone below.

in Kern County, California, show a SiO_2 content of 7 percent.[6] Additional analyses from the Bissell deposit by the U. S. Geological Survey show insolubles ranging from 4.75 percent to 10.6 percent.[7] Analyses of specimens from the Bissell deposit, which had been exposed to weathering for several seasons, showed 5 to 10 percent SiO_2. The combined Al_2O_3 and Fe_2O_3 content in the analyzed specimens from the Bissell deposit is much higher in general than in those from the Needles deposit. The published analyses range from 0.76 percent to 10.05 percent R_2O_3, with the greater number of analyses showing slightly more than 2 percent. At Needles the R_2O_3 content (combined Al_2O_3 and Fe_2O_3) in all analyzed specimens is very low. In only three specimens was there more than 1 percent R_2O_3, and none contained more than 1.9 percent.

In the Afton magnesite deposit in San Bernardino County, California, the insoluble content analyzed in specimens taken by the U. S. Geological Survey ranges from 5.1 percent to 26.4 percent. The total Al_2O_3 and Fe_2O_3, analyzed separately in the specimens from this deposit, is more than 3 percent in all the specimens in which these constituents were determined.[8] The magnesite from the Horse Spring formation at Overton, Clark County, Nevada, is another example of sedimentary magnesite in which the tenor of the ore is lower than at the Needles magnesite deposit. All of the specimens analyzed from this deposit show an insoluble content in excess of 10 percent.[9] In the Bauer magnesite deposit, also in Clark County, Nevada, the analyses show an insoluble content ranging from 4 to 6.2 percent.[10]

The consistently lower content of insolubles and R_2O_3 in the magnesite from the Needles deposit is of considerable interest, especially in view of the fact that this deposit was considered as a possible source of ore for the Basic Magnesium, Inc., plant at Las Vegas, Nevada, during the early part of World War II.

Origin. The origin of magnesite of the sedimentary type has been discussed by Longwell [11] and by Rubey and Callaghan.[12] Longwell has suggested that the magnesite in the Overton magnesite deposit was probably deposited as a sediment in a playa lake. The source of the magnesium is given as hot springs of deep-seated origin at a time of widespread dolomitization in the area.

Rubey and Callaghan have concurred with Longwell on the sedimentary origin of the magnesite in the Overton magnesite deposit. The exceedingly fine grain of the carbonates, the excellent preservation of all details of depositional bedding, the diverse composition of successive thin beds, and the uniform composition of individual beds traced laterally are stated as evidence of a sedimentary origin. In connection with the problem of the origin of sedimentary magnesite, some experimental work was done in the laboratories of the U. S. Gelogical Survey by P. G. Nutting and R. C. Wells on the solubility of magnesite, dolomite, and parasepiolite. Based upon the assumption that waters coming into the playa lake at the time of the formation of the Overton magnesite deposit were highly magnesian, it was shown that composition, concentration, and temperature, plus environmental conditions, would govern what phase would be deposited or dissolved at any given time. Thus, either magnesite, dolomite, or parasepiolite could be deposited at one time, and at a later time any phase could be dissolved and removed.

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[6] Bradley, W. W., Magnesite in California: California Min. Bur. Bull. 79, p. 49, May 1925.

[7] Rubey, W. W., and Callaghan, Eugene, op. cit., p. 116.

[8] Bradley, W. W., op. cit., pp. 72-75.
Rubey, W. W., and Callaghan, Eugene, op. cit., pp. 117-118.

[9] Rubey, W. W., and Callaghan, Eugene, idem., pp. 119-139.

[10] Rubey, W. W., and Callaghan, Eugene, idem., pp. 140-141.

[11] Longwell, C. R., Geology of the Muddy Mountains, Nevada: U. S. Geological Survey Bull. 798, pp. 82-85, 1928.

[12] Rubey, W. W., and Callaghan, Eugene, op. cit., pp. 134-138.

Similarly, at Needles, California, the uniformity of thin laminations, the well-preserved depositional bedding, continuous laterally for hundreds of feet, the persistence of partings of material higher in CaO and SiO_2 content, and concordance with both overlying and underlying sedimentary rocks indicate a sedimentary origin for the magnesite in this area. The magnesite and the associated sedimentary rocks were deposited in an inland lake.

Although the magnesite beds at Needles are of sedimentary origin, the source of the magnesium in the waters flowing into the lake is not definitely known. It is suggested that spring water rising through the andesitic volcanic rocks which underlie the carbonate rocks in the area may have dissolved some of the magnesium from the volcanics. It is probable, however, that a deeper-seated source was responsible for most of the magnesium carried by the water entering the lake.

Estimate of Ore Reserves at the Needles Deposit. The factors which required consideration in estimating the reserves of magnesite at the Needles deposit are the contorted condition of the magnesite beds, the variation in the thickness of the beds from outcrop to outcrop, and the lack of sufficient information on the lateral extent of the magnesite lens, particularly in the northeastern part of the mapped area.

In order to facilitate estimation of the magnesite reserves, the ore-bearing area was divided into eight parts (see pl. 62), each of which was treated as a separate ore body. The final estimates are the summations of the eight separate ore blocks.

Description of the ore-bearing areas.

Area No. 1	This area contains the southernmost magnesite outcrops of any consequence. The sedimentary rocks are folded into a syncline bounded on the west by a normal fault. The magnesite in this area may be overlain by as much as 200 feet of consolidated sedimentary rock and alluvium (pl. 64, section II′).
Area No. 2	The generalized structure of the sedimentary rocks in area No. 2 is a gentle syncline on the west passing over to an anticline on the east and bounded on the eastern edge by a normal fault. The magnesite in this area is overlain by not more than 50 feet of consolidated sediments and alluvium (pl. 64, section GG′).
Area No. 3	In area No. 3 the sedimentary rocks are highly folded, and they are bounded on the west by a fault. The magnesite ore determined in this area is calculated entirely as "inferred" (pl. 64, section HH′).
Area No. 4	In area No. 4 the sedimentary rocks are highly folded. The magnesite outcrops at the east side are cut off on the west by a fault (pl. 64, section II′).
Area No. 5	The rocks in area No. 5 are folded into a gentle anticline and syncline. Area No. 5 contains the largest outcrops of magnesite ore in the deposit. The magnesite in this area is overlain by a maximum of about 100 feet of sedimentary rock and alluvium (pl. 64, section EE′).
Area No. 6	In area No. 6 the sedimentary rocks are folded into a gentle northward-plunging anticline. The magnesite in area No. 6 is estimated as mostly "measured ore" and occurs near the surface (pl. 64, sections BB′ and CC′).

Area No. 7 In area No. 7 the beds of the sedimentary rocks are highly folded. Area No. 7 is a continuation of area No. 6. The magnesite in this area is estimated as "inferred ore," and may have a maximum overburden of 150 feet (pl. 64, sections DD′ to BB′).

Area No. 8 Area No. 8 is the eastward extension of areas No. 5 and No. 7. The sedimentary rocks in area No. 8 are a series of northward-plunging folds. In this area the magnesite is estimated entirely as "inferred ore" (pl. 64, sections FF′ to CC′).

Reserves were computed as ''indicated ore'' where positive information such as sample pits, diamond drill holes, and outcrops indicate the occurrence of magnesite, and as ''inferred ore'' where no exploratory information was available, and the assumption of the existence of magnesite was based solely upon the projection of surface geology. In addition, a certain amount of ore reserves were calculated as existing beyond a depth of 50 feet down the dip from all outcrops and sample pits. The estimated reserves in this last category are included under ''inferred ore.''

The grade of the ore was determined from samples taken and analyzed by the U. S. Geological Survey, augmented by analyses made by the California Chemical Corp. Almost all the samples were taken from the pits excavated by the California Chemical Corp. The analyses from each area were weighted and averaged. The reserves were calculated on the basis of (1) less than 5 percent CaO, (2) more than 5 percent and less than 10 percent CaO, and (3) more than 10 percent CaO.

Table 3. Summary of estimated ore reserves *

Area	Tons of indicated ore			Tons of inferred ore		
	5 percent CaO	5-10 percent CaO	10+ percent CaO	5 percent CaO	5-10 percent CaO	10+ percent CaO
1	2,000	2,000	5,000	10,000	20,000	40,000
2				5,000	5,000	7,000
3	2,000	5,000	7,000			
4	1,000					
5	35,000	45,000	45,000			
6				100,000	120,000	
7	25,000			150,000		
Totals	65,000	52,000	57,000	265,000	145,000	47,000

* Estimates of 117,000 tons of "indicated ore" and 410,000 tons of "inferred ore" are made for the Needles magnesite deposit, based upon a maximum limit of 10 percent CaO.

In attempting to mine the magnesite ore on a commercial basis the variation in thickness of the overburden, the grade of ore and its variation, the lack of water at the mine, and the need for an access road must be taken into account. The variation in thickness of overburden depends mainly upon the geologic structure. The cross sections depict the condition which may be expected at any given point in the Needles magnesite-bearing area. The grade of ore which may be expected and the variation from place to place are shown in tables 4 and 5. Water probably could be developed somewhere in the vicinity of the deposit. A few moist spots were observed along the Eagle Wash road between the city of Needles and the magnesite deposit. Improvement of the present access roads would solve the transportation problem. Metallurgical treatment of the ore would require some means of controlling dust losses in view of the tendency of the ore to powder readily upon exposure.

Table 4. Chemical analyses. Samples by U. S. Geological Survey.

Number	Area	Insol. 1:3 HCl	R_2O_3	CaO	MgO	$CaCO_3$ (calc.)	$MgCO_3$ (calc.)
N-1	1.	2.66	0.32	0.48	44.22	0.86	92.50
N-2	1.	5.43	0.36	25.46	23.31	45.40	48.81
N-3	1.	2.67	0.20	7.59	39.98	13.52	83.61
N-4	1.	1.66	0.88	26.76	22.52	47.76	47.12
N-5	1.	10.26	0.72	2.06	39.62	3.68	82.86
N-6	1.	11.14	1.58	22.78	21.73	40.66	45.54
N-7	1.	5.54	0.74	27.00	21.62	48.18	45.24
N-8	1.	7.18	0.54	26.08	21.48	46.54	44.94
N-9	1.	6.32	0.80	25.50	21.64	45.52	45.26
N-10	2, 5	1.38	0.40	1.10	46.32	1.96	96.20
N-11	2.	1.34	0.18	0.78	43.84	1.39	91.70
N-12	2.	2.34	0.18	1.00	45.72	1.78	95.70
N-13	2.	5.24	1.90	17.38	28.22	31.02	59.00
N-14	2.	1.34	0.88	7.16	39.41	12.78	82.46
N-15	2.	7.83	0.49	1.22	42.79	2.18	89.50
N-16	2.	3.76	0.12	0.30	45.69	0.54	95.58
N-17	2, 3	3.48	1.04	10.58	36.24	18.88	75.78
N-18	2, 3	5.60	0.76	5.56	39.92	9.92	83.48
N-19	2, 3	6.90	0.98	15.06	28.99	26.88	60.63
N-20	2, 3	10.34	0.92	8.26	34.42	14.74	72.00
N-21	2, 3	0.46	0.48	4.46	43.08	7.96	90.12
N-22	3, 4	2.52	0.53	4.44	42.61	7.92	89.03
N-23	5, 6	2.50	0.33	2.58	44.24	4.60	92.57
N-24	5, 6	7.52	0.79	1.72	42.39	3.07	88.62
N-25	5, 6	7.32	0.42	6.70	38.48	11.96	80.46
N-26	5, 6	2.20	0.32	3.86	42.60	6.89	89.12
N-27	5, 6	7.49	0.19	5.59	39.34	9.98	82.34
N-28	5, 6	1.74	0.44	16.30	32.20	29.09	67.34
N-29	5, 6	0.78	0.24	6.06	41.12	10.82	86.02
N-30	5, 6	7.98	0.70	6.64	37.68	11.85	78.82
N-31	5, 6	7.52	0.68	5.64	39.00	10.07	81.58
N-32	5, 6	6.86	0.88	11.42	32.12	20.38	67.18
N-33	5, 6	3.10	0.50	2.30	42.32	4.10	88.64
N-34	5, 6	4.42	0.62	0.60	44.54	1.07	93.16
N-35	5, 6	8.62	0.80	13.00	31.86	23.20	66.64
N-36	5, 6	10.45	0.38	8.30	35.51	14.80	74.37
N-37	7.	2.56	0.68	1.70	44.44	3.03	92.96
N-38	7.	1.52	0.32	0.86	44.62	1.53	93.34
N-39	7.	4.08	0.36	1.68	43.88	3.00	91.78
N-40	7.	6.04	0.76	8.84	34.42	15.78	71.98
N-41	7.	1.82	0.86	1.78	43.20	3.18	90.36
N-42	7.	11.06	0.98	7.50	32.04	13.39	67.00
N-43	7.	10.46	0.48	6.94	36.68	12.38	76.68

N– 1 Field number 63, channel sample to represent 2 feet, white, rather blocky magnesite, from trench 63. Norman Davidson, analyst.

N– 2 Field number 63b, channel sample to represent 3.2 feet, white blocky dolomite, just below N–1 in trench 63. V. North, analyst.

N– 3 Field number 63c, channel sample to represent 3 feet, white, thin-bedded, impure magnesite, just below N–2 in trench 63. N. North, analyst.

N– 4 Field number 65a, channel sample at top of the face of trench 65 to represent 1.7 feet, thin-bedded, white dolomite. Norman Davidson, analyst.

N– 5 Field number 65b, channel sample at bottom of the face of trench 65 to represent 2.3 feet of rather blocky magnesite. Norman Davidson, analyst.

N– 6 Field number 66, channel sample to represent 3.3 feet of impure dolomite across face of trench 66. Norman Davidson, analyst.

N–7 Field number 67, channel sample to represent 3.9 feet of blocky dolomite across the face of trench 67. Norman Davidson, analyst.

N–8 Field number 68f, channel sample to represent 4.5 feet of dolomite across face of trench 68. Norman Davidson, analyst.

N–9 Field number 68w, channel sample to represent 4 feet of dolomite along wall of trench 68. Norman Davidson, analyst.

N–10 Field number 4a, channel sample to represent 2.5 feet of magnesite in trench 4. Norman Davidson, analyst.

N–11 Field number 9, channel sample to represent 3.5 feet of magnesite in south wall of trench 9 ; 10 feet from the face. Norman Davidson, analyst.

N–12 Field number 14, channel sample to represent 4 feet of thin-bedded white magnesite in the south wall of trench 14. V. North, analyst.

N–13 Field number 15, channel sample to represent 3.4 feet of magnesitic dolomite across the face of trench 15. Norman Davidson, analyst.

N–14 Field number 16, channel sample to represent 1.2 feet of white unconsolidated dolomitic magnesite in trench 16. Norman Davidson, analyst.

N–15 Field number 31a, channel sample to represent 3.5 feet of magnesite in face of trench 31. V. North, analyst.

N–16 Field number 32, channel sample to represent 2.7 feet of massive magnesite in the north wall of trench 32. V. North, analyst.

N–17 Field number 39, channel sample to represent 2.5 feet of dolomitic magnesite from face to trench 39. Norman Davidson, analyst.

N–18 Field number 40a, channel sample to represent 1.3 feet of thin-bedded magnesite in trench 40. Norman Davidson, analyst.

N–19 Field number 49b, channel sample to represent 0.8 feet of thin-bedded impure magnesite just below sample N–13 in trench 40. Norman Davidson, analyst.

N–20 Field number 40c, channel sample to represent 1.3 feet of clay gouge below sample N–19 in trench 40. Norman Davidson, analyst.

N–21 Field number 45, channel sample to represent 1.9 feet of magnesite in the south wall of trench 45. Norman Davidson, analyst.

N–22 Field number 61, channel sample to represent 1.3 feet of magnesite in south wall of trench 61. V. North, analyst.

N–23 Field number 5a, channel sample to represent 1.7 feet of magnesite in trench 5. V. North, analyst.

N–24 Field number 5b, channel sample to represent 2.8 feet of impure magnesite just below sample N–23 in trench 5. V. North, analyst.

N–25 Field number 6, channel sample to represent 5.1 feet of thin-bedded magnesite and thin shaly partings combined in trench 6. Norman Davidson, analyst.

N–26 Field number 8a, channel sample to represent 1.7 feet of thin-bedded impure magnesite in trench 8. Norman Davidson, analyst.

N–27 Field number 8b, channel sample to represent 3.9 feet of impure magnesite directly below N–26 trench 8. V. North, analyst.

N–28 Field number 11a, channel sample to represent 1 foot of magnesitic dolomite in south wall of trench 11. Norman Davidson, analyst.

N–29 Field number 11b, channel sample to represent 3 feet of impure magnesite on top of sample N–28 in trench 11. Norman Davidson, analyst.

N–30 Field number 21, channel sample to represent 2.5 feet of impure magnesite in trench 21. Norman Davidson, analyst.

N–31 Field number 22, channel sample to represent 1 foot of impure magnesite in trench 22. Norman Davidson, analyst.

N–32 Field number 28a, channel sample to represent 2.3 feet of thin-bedded dolomitic magnesite on hanging wall of small fault in trench 28. Norman Davidson, analyst.

N–33 Field number 28b, channel sample to represent 3.5 feet of magnesite in footwall of small fault in trench 28. Norman Davidson, analyst.

N–34 Field number 29a, channel sample to represent 2.9 feet of thin-bedded magnesite in trench 29. Norman Davidson, analyst.

N–35 Field number 29b, channel sample to represent 2.3 feet of dolomitic magnesite underneath N–34 and separated from it by 1.6 feet of shale and dolomite. Norman Davidson, analyst.

N–36 Field number 34a, b, and c, combined channel sample to represent 3.9 feet of magnesite and shaly partings in trench 34. V. North, analyst.

N–37 Field number 7, channel sample to represent 2.3 feet of magnesite in trench 7. Norman Davidson, analyst.

N–38 Field number 12a, channel sample to represent 2 feet of magnesite below unconformity in trench 12. Norman Davidson, analyst.

N–39 Field number 23a, channel sample to represent 1.7 feet of magnesite in footwall of shear zone in trench 23. Norman Davidson, analyst.

N–40 Field number 23b, channel sample to represent 0.8 foot of magnesite in hanging wall of shear zone in trench 23. Norman Davidson, analyst.

N–41 Field number 25, channel sample to represent 3.0 feet of magnesite in trench 25. Norman Davidson, analyst.

N–42 Field number 35, channel sample to represent 3.4 feet of dolomitic magnesite in trench 35. Norman Davidson, analyst.

N–43 Field number 36a, b, and c, combined channel sample to represent 4.8 feet of dolomitic magnesite in trench 36. V. North, analyst.

Table 5. Chemical analyses of samples from the Needles magnesite deposit. Samples taken and analyzed by Westvaco Chlorine Products Corporation.

Ore samples					
Sample number	CaO	$CaCO_2$	SiO_2	Fe_2O_3	Al_2O_3
3261	1.03	1.84	3.35	.03	.015
3254	.53	.95	1.49	.03	.25
3255	2.68	4.79	1.64	.04	.12
3263	1.56	2.79	1.95	.02	.17
3268	.91	1.63	3.52	.08	.36
3264	4.84	9.53	3.31	.04	.14
3283	2.23	3.98	1.85	.05	.24
3276	1.28	2.29	1.19	.04	.13
3252	.48	.85	.48	.09	.08
3289	7.57	13.52	2.88	.05	.20
3284	.60	1.08	4.35	.04	.16
3226	1.56	2.78	3.45	.03	.07
3202	20.86	37.40	1.68	.03	.25
3203	4.82	8.60	1.20	.04	.16
3207	21.30	38.00	3.54	.05	.37
3208	7.94	14.20	8.88	.05	.43

Sample number	Sample width represented	Sample locality
3261	3 feet	Pit No. 1, area 2
3254	2 feet	Pit No. 3, area 2
3255	3 feet	Pit No. 3, area 2
3263	6 feet	Pit No. 3, area 2
3268	3 feet	Pit No. 7, area 1
3264	6 feet	Pit No. 10, area 2
3283	2 feet	Pit No. 13, area 4
3276	3 feet	Pit No. 24, area 2
3252	Sample from outcrop	Pit No. 26, area 2
3289	1 foot	Pit No. 27, area 2
3284	2 feet	Pit No. 31, area 4
3226	2 feet	Pit No. 39, area 4
3202	5 feet	Pit No. 62, area 3
3203	3 feet	Pit No. 62, area 3
3207	5.5 feet	Pit No. 64, area 3
3208	2 feet	Pit No. 64, area 3

Capitan Deposit

The Capitan deposit consists of six claims held by O. Hendrickson, G. W. Justice, and T. Hayes of Needles, California. When the writer first visited the area in 1943, a small amount of prospecting represented the only work done on this deposit. When the area was revisited in May 1944, an exploratory program was in progress at this deposit. Two large pits had been excavated, in one of which magnesite was exposed.

White, thinly laminated magnesite of sedimentary origin occurs in a series of thin-bedded Tertiary dolomitic limestone. The sediments are strongly folded, but the same types of intricate minor folds and faults so prominent in the magnesite at the Needles deposit were not noticed in the Capitan deposit. The steeply dipping sediments are covered by a thin veneer of alluvium, through which the more resistant dolomitic limestone crops out intermittently. The conformable relationship between the magnesite beds and the associated sediments indicates the sedimentary origin of the magnesite.

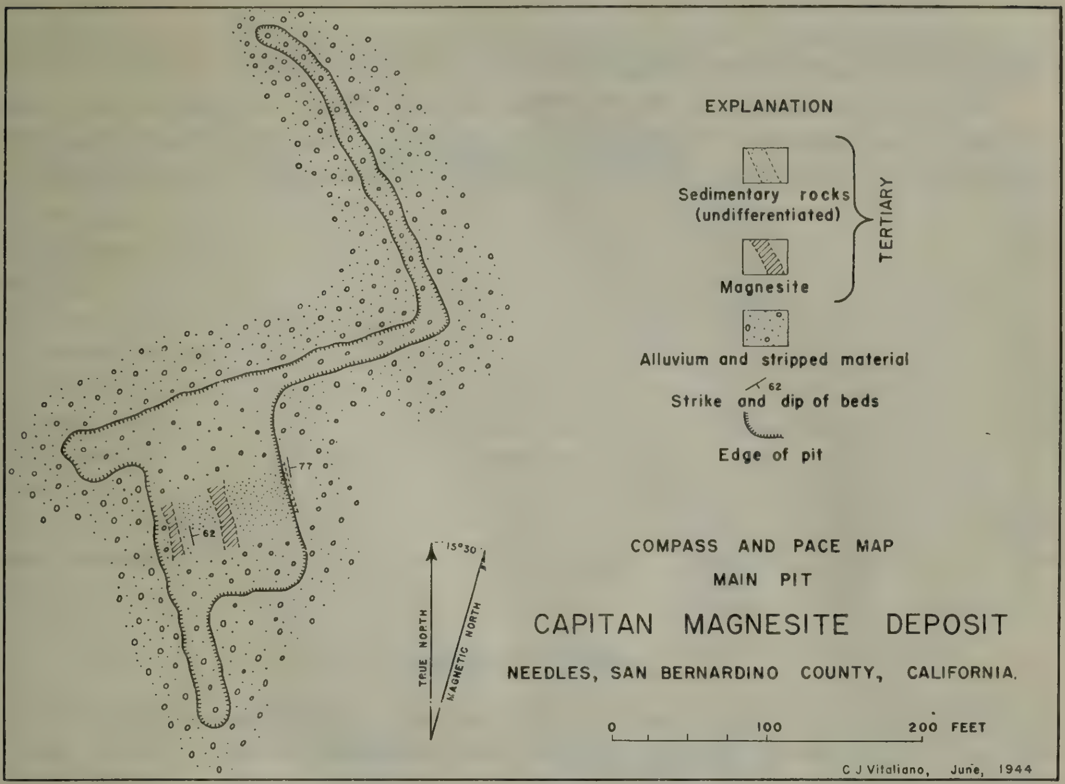
EXPLANATION
Sedimentary rocks (undifferentiated)
Magnesite
TERTIARY
Alluvium and stripped material
62
Strike and dip of beds
Edge of pit
77
62
15°30'
TRUE NORTH
MAGNETIC NORTH
COMPASS AND PACE MAP
MAIN PIT
CAPITAN MAGNESITE DEPOSIT
NEEDLES, SAN BERNARDINO COUNTY, CALIFORNIA.
0
100
200 FEET
C J Vitaliano, June, 1944

FIGURE 2. Compass and pace map of the main pit, Capitan magnesite deposit, Needles, San Bernardino County, California.

The magnesite is white, fine-grained, rather porous, and of lower specific gravity than the magnesite of the Needles deposit. The ore crops out in two parallel bands, each approximately 8 feet thick and dipping 62° NE. (fig. 2). Whether the two bands are outcrops of two separate beds or of the two limbs of an isoclinal fold is not certain.

No estimate of the magnesite reserves in the Capitan deposit was made because the exploration program was not far enough along at the

Table 6. Chemical analyses of samples from the Capitan magnesite deposit, Needles, California *

Sample number	CaO	MgO	R_2O_3	Insoluble material	Loss
1	1.4	45.1	0.2	4.3	49.1
2	1.1	44.7	0.2	5.1	48.7
3	1.1	46.3	0.3	2.5	49.8
4	2.1	44.3	0.2	4.6	48.8
5	3.8	44.2	0.6	1.6	49.7
6	2.5	45.3	0.3	2.5	49.9
7	3.1	44.1	0.76	3.9	48.1

* Samples 1-7. Analyses of picked samples from widely scattered places in deposit. Samples taken by Basic Magnesium, Inc., Las Vegas, Nevada. Analyst, Basic Magnesium, Inc., Las Vegas, Nevada.

time of the last examination to provide sufficient data. Chemical analyses of selected samples (table 6) show a low content of CaO and moderate amounts of insoluble material.

Mining operations at the Capitan deposit would be confronted with the same problems as at the Needles deposit. Transportation, however, would not be so difficult, as the property is considerably more accessible.

NORTHERN CALIFORNIA AS A MARKET FOR CHEMICALS *

E. WILLIAM EIPPER, EDITOR **

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INTRODUCTION

Northern California, particularly the nine counties comprising the "Bay Area," has witnessed a remarkable growth in the chemical and chemical consuming industries. Central location for serving the western market along with excellent availability of rail, water, motor and air transportation, manpower, public utilities, industrial sites, and natural resources have encouraged industrial expansion of all types. To be more specific the investment in new plants and in plant expansions in the area has amounted to almost $400,000,000 during the first four post-war years. An appreciable increase in chemical and petrochemical activity in the area has taken place and has contributed to this impressive total. Industrial expansion of this magnitude in the chemical manufacturing and chemical consuming industries has materially increased the market for chemicals.

The information which we will present is incomplete but affords a preview of northern California as a market for chemicals. Though a wide variety of chemical consuming industries are located in the area, it has been possible to estimate satisfactorily the chemical consumption of only a limited number. These we will consider individually.

PLASTICS AND RESINS

Plastics manufacture, that is the production of the chemical monomer or polymer, is almost non-existent in the area. There is, however, a modest sized molding industry which we estimate consumes the following quantities of molding compounds:

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* A cooperative report by members of the Western Chemical Market Research Group, San Francisco. Paper for presentation at Pacific Industrial Conferences, Pacific Chemical Exposition, November 1, 1949. Originally released in mimeograph form by the Industrial Department of the San Francisco Chamber of Commerce.

** Oronite Chemical Co.

The editor wishes to acknowledge the assistance of the following co-authors: Kenneth Bayha, Commercial Solvents Corporation; Raymond H. Ewell, Stanford Research Institute; William E. Hosken, Stanford Research Institute; Herman J. Jordan, E. I. du Pont de Nemours & Co., Inc.; Richard F. Schlecht, Standard Oil Co. of California; and Charles D. Thurmond, Monsanto Chemical Company.

Molding compound	Pounds per year
Polystyrene	400,000
Cellulose acetate (and acetate-butyrate)	400,000
Thermosetting resins (mostly phenol-formaldehyde)	900,000

Likewise, there is a reasonable consumption of liquid laminating resins, estimated to be about 1,250,000 pounds a year of product containing 70 percent solids.

The production of resins is a larger field. There is an installed alkyd resin kettle capacity totalling over 35,000 gallons, 60 percent attributable to one resin producer and the remainder to about nine paint manufacturers.

The production of phenolic resins has leaped ahead due to a new local requirement for a phenolic bonding resin. Oil soluble varnish resins are also produced and there is one manufacturer of ion-exchange resins.

Total consumption of the principal chemicals used in resin production in Northern California is estimated:

Resin production	Pounds per year
Phthalic anhydride	5,000,000
Maleic anhydride	500,000
Other acids	100,000
Glycerine	2,225,000
Pentaerythritol	750,000
Ethylene glycol	200,000
Oils and fatty acids	12,000,000
Phenol	1,750,000
Formaldehyde	1,850,000
Solvents	15,000,000

Other chemicals are used in minor quantities.

SURFACE COATINGS

Drawing from a wide variety of government and other publications, and making certain assumptions, we have developed a series of estimates which we will present in very condensed form.

Based upon the value of finished products in 1947 and the 1948 index of production it is estimated that the surface coatings industry in California represents approximately 10 percent of the national industry. This represents commercial production only and does not include the considerable production by the U. S. Navy at the Mare Island Navy Yard. All of our data are based on the Census of Manufactures. It does not include data collected from government facilities.

The northern California production is less than half the total for the state, but would probably exceed this level if the production by the Mare Island Navy Yard were included. Though the pattern of chemical consumption by the paint industry in California is reasonably identical to the national pattern, there is some deviation within the state. We will therefore enlarge all our estimates to include the industry on a state-wide basis, but excluding the Navy production.

Those interested in estimating the requirements of either the northern California or southern California industry may respectively take 40 percent and 60 percent of our figures as reasonable approximations. Likewise, a rough estimate of the west coast requirements outside of California could be obtained by taking about 15 percent of our figures.

To begin with it is estimated that the finished products of the California surface coatings industry amounted to over $120,000,000 in 1948.

Finished products	Gallons per year
Oil pigment paints [1]	18,650,000
Varnishes	9,500,000
Nitrocellulose lacquers	7,650,000
All other lacquers	1,550,000
Enamels	9,000,000
Bituminous paints	1,800,000
Water thinned paints	1,650,000
Stains	900,000
Spirit varnishes	700,000
Metallic paints	600,000
Total	52,000,000

[1] Includes miscellaneous paints not included in other categories.

The raw materials are divided into five general classifications, some of which are further subdivided. Let us examine and discuss tables 1 to 5 inclusive.

In the field of white pigments (table 1) it is of interest that titanium dioxide has now reached about 50 percent of the total. The estimate may be low on this item.

Colored pigments (table 1) were more difficult to estimate, particularly the organic lakes and toners, chrome colors, and the mineral earth colors. The latter appear to represent approximately 50 percent of the total colored pigments.

The extender pigments (table 1), commonly used in the lower cost whites and calcimines, amount to more than we anticipated.

In the field of drying oils (table 2) linseed oil is still the large volume item with consumption running about three times that of either soybean oil or tung oil. Dehydrated castor oil appears to be gaining favor.

In the field of resins (table 3) alkyds are dominant. Our figure includes all types of alkyds and modified alkyds.

''Other synthetic resins'' includes vinyl resins, polystyrene, acrylic esters, silicones, rubber derivatives, coumarone-indene resins, and other products.

Rosin is the principal natural resin used; as indicated our figure does not include the quantity used to make esters and adducts. The consumption of the other natural resins is difficult to estimate.

We have made our estimates on solvents (table 4) in gallons instead of in pounds as in the other tables. Petroleum solvents represent over two-thirds of all solvents used without inclusion of toluene and xylene which could also be from petroleum sources. We have included both low and high boiling alcohols in one figure though the ethanol and propanol probably represent over two-thirds of the total. The biggest items in the ester and ketone group are ethyl acetate, n-butyl acetate, methylethyl ketone and methylisobutyl ketone, though others are used in smaller quantities.

Among the miscellaneous materials (table 5) we have included chemical plasticizers. This figure is probably largely the phthalate esters and tricresyl phosphate.

Table 1. Estimated raw material consumption, California surface coatings industry, 1948.

PIGMENTS	Pounds per year
White Hiding Pigments	
White lead	8,200,000
Lithopone	20,900,000
Zinc oxide	5,400,000
Leaded zinc oxide	13,000,000
Titanium dioxide	46,500,000
Total	94,000,000
Colored Hiding Pigments	
Organic lakes and toners	1,600,000
Chrome colors	3,600,000
Inorganic blues	800,000
Red lead	2,200,000
Litharge	900,000
Mineral earth colors	11,700,000
Carbon and lampblack	1,200,000
Metal powders	1,000,000
Total	23,000,000
Extender Pigments	
Talc	21,900,000
Whiting	11,100,000
Silica	6,000,000
Barite	6,000,000
Clay	4,700,000
Mica	2,800,000
Other extenders	1,500,000
Total	54,000,000
Total pigments	171,000,000

Table 2. Estimated raw material consumption, California surface coatings industry, 1948.

Drying oils	Pounds per year
Linseed oil	31,300,000
Soybean oil	10,000,000
Tung oil	9,200,000
Dehydrated castor oil	3,800,000
Other oils [1]	4,700,000
Total	59,000,000

[1] Includes non-dehydrated castor oil.

Table 3. Estimated raw material consumption, California surface coatings industry, 1948.

Resins	Pounds per year
Synthetic Resins	
Alkyd resins	28,000,000
Phenolic resins	5,700,000
Urea and melamine resins	2,400,000
Rosin esters	6,300,000
Rosin adducts	500,000
Nitrocellulose	3,800,000
Other cellulose derivatives	300,000
Other synthetic resins	3,000,000
Total	50,000,000
Natural Resins	
Rosin [1]	6,700,000
Shellac	2,200,000
Copal, damar, and other fossil resins	1,500,000
Casein and other proteins	1,600,000
Total	12,000,000
Total resins	62,000,000

[1] Does not include rosin to make rosin esters and rosin adducts.

Table 4. Estimated raw material consumption, California surface coatings industry, 1948.

Solvents	Gallons per year
Petroleum solvents	21,000,000
Toluene, xylene and coal tar naphthas	2,700,000
Turpentine	1,700,000
Alcohols	1,900,000
Esters, ketones, and alcohol-ethers	2,700,000
Total	30,000,000

Table 5. Estimated raw material consumption, California surface coatings industry, 1948.

Miscellaneous	Pounds per year
Chemical plasticizers [1]	1,000,000
Driers [2]	3,000,000
Asphalt and pitch	10,000,000
Total	14,000,000

[1] Includes phthalate and phosphate esters, does not include castor oil.

[2] Naphthenates, linoleates, tallates, resinates, oleates, etc.

Driers are used in all types of coatings which use drying oils. They are the metallic salts (for example, cobalt, lead, manganese) of various acids and include the naphthenates, linoleates, tallates, oleates, resinates, 2-ethylhexoates and others.

PROCESSING OF NATURAL OILS

The conditioning of vegetable, animal, and fish oils for use in edible products, and in the production of surface coatings is a sizable field. It is interesting to note that the utilization of natural oils (on a national basis) is distributed about 70 percent for edible use, 20 percent for soap, and only 10 percent for the production of coatings and resins, though chemicals find their largest application in the upgrading of oils for the latter use.

Though quantitative information for this area is unavailable, some of the principal chemicals used include:

Salt
Sulfuric acid
Caustic soda
Lime
Soda ash
Hydrogen
Catalysts
Maleic anhydride
Pentaerythritol
Styrene
Dicyclopentadiene

PETROLEUM REFINING

The northern California petroleum refining industry consists of the local installations of the four major companies. These companies use somewhat different refining processes and a chemical which is a large volume item at one refinery may not be procured at all by the other three. The complete list of chemicals purchased may include several hundred items, yet as pointed out by E. H. Weaver,[1] about 40 items represent approximately 85 percent of the chemical expense. He published the first ten chemicals based upon dollar value; we have developed a similar list but have taken the chemicals used in the greatest tonnage in northern California. Our list includes most of Weaver's ten products; we have added tetraethyl lead compound and litharge.

Estimated consumption of chemicals in northern California petroleum refining industry—ten largest volume products

	Pounds per year
Sulfuric acid	280,000,000
Caustic soda	60,000,000
Tetraethyl lead compound	16,000,000
Tallow and fatty acids	6,500,000
Catalysts	6,000,000
Ammonia	4,000,000
Phenol	3,200,000
Methylethyl ketone	2,500,000
Sulfur dioxide	2,000,000
Litharge	2,000,000

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[1] Weaver, E. H., The western petroleum industry as a consumer of chemicals: Paper presented before Western Chem. Market Research Group, Pacific Chem. Exposition, San Francisco, October 21, 1947.

The industry procures several million pounds of crude bulk salt per year, but it is believed that this is not for direct process use and was, therefore, not included in our table.

A word regarding the relationship of the industry in northern California to the statewide industry and the national total may be of interest. The refining in California comprises about one-sixth of the national total and northern California has about one-third of the state's total or a little over 5 percent of the national total. This can be based on total potential crude oil consumption or cracking capacity, as shown:

	Northern California	California	U.S.
Crude oil charge capacity, B/D	330,800	1,047,800	6,515,500
, % U.S.	5.1	16.1	
, % Calif.	31.6		
Cracking capacity, B/D [1]	[2] 209,600	518,150	3,752,400
, % U.S.	5.6	15.4	
, % Calif.	36.3		
Employment (Prod. and related works—, Dec. 1948)	5,100	12,400	113,300
% U.S.	4.5	10.9	
% Calif.	41.1		

[1] Thermal cracking, catalytic cracking, and reforming.

[2] Includes 42,000 B/D crude oil feed to thermal cracking and coking processes.

AGRICULTURE

California agriculturists are unusually progressive in their scientific approach to crop production. This is attributable to factors such as crop specialization and the necessity for producing a high quality product to compete in the eastern market.

Chemical manufacturers, government laboratories, and agriculturists cooperate in the continuing evaluation of both new and old chemicals in terms of the need to be filled and the potential economic realization. This method seems to be very satisfactory. Cash farm income in 1948 was approximately $2,000,000,000 derived from over two hundred types of crops.

Chemicals played an important part in the production of this wealth as evidenced by these expenditures for California (estimated by the State Bureau of Chemistry):

Commercial fertilizers	$42,000,000
Economic poisons	20,000,000
Agricultural minerals	6,000,000
Auxiliary plant chemicals	2,000,000
Total	$70,000,000

Fertilizer consumption has increased markedly with a 1948 California consumption of approximately 550,000 tons compared to the

1937-41 prewar average of about 230,000 tons per year. The pattern of use may be of interest and the reported segregated tonnage is shown in table 6.

Table 6. California consumption of commercial fertilizers, segregated commercial fertilizer tonnage, 1948.

Material	Tons	Material	Tons
Mixed fertilizers	207,209	Potassium sulfate	3,200
Superphosphate, normal	70,590	Urea	1,447
Ammonium sulfate	69,827	Bone meal	1,168
Ammonium nitrate	41,078	Blood meal	922
Ammonium phosphate-sulfate	31,602	Tankage	735
Superphosphate, treble	17,092	Fish meal	557
Sodium nitrate	11,983	Seed meals	447
Nitrogen solutions	11,977	Ammoniated superphosphate	410
Mixed fertilizers, liquid	10,732	Ammonium phosphate-nitrate	200
Calcium cyanamid	8,289	Miscellaneous	3,599
Calcium nitrate	8,152	Not segregated by registrant	26,559
Sewage sludge, activated	7,220	Correction by audit	1,170
Ammonium phosphate	6,011		
Potassium chloride	3,335	Total	548,744
Liquid phosphoric acid	3,233		

Agricultural mineral sales for 1948 in California reached almost 500,000 tons about 70 percent of which was gypsum used as a soil conditioner. The segregated tonnage is shown in table 7.

Table 7. California sales of agricultural minerals, segregated agricultural minerals tonnage, 1948.

Material	Tons	Material	Tons
Gypsum	349,979	Hydrated lime	1,130
Sewage sludge	28,920	Phosphate rock	364
Soil sulphur	20,304	Miscellaneous *	20,759
Limestone and shells	12,697	Not segregated by registrant	1,243
By-product lime	10,927	Correction by audit	587
Mixed goods	3,581		
Metallic salts	1,392	Total	451,883

* Includes lime sulfur solution 3,728 tons, sulfur dioxide 708 tons, sulfuric acid 10,593 tons.

The field of economic poisons has been marked by a high rate of obsolescence and a rapid and widespread acceptance of the variety of newly developed organic pesticides. These products have had some acceptance problems, many of which can be attributed to improper utilization. The arsenicals declined with the advent of the organics. Products which were in the experimental stages in 1948, but are now expanding, include lindane (99 percent gamma isomer of hexachlorocyclohexane) and parathion. In the field of herbicides much remains to be accomplished in developing better means of controlled application and in straightening out the liability problems encountered.

Table 8. Estimated pesticide consumption in northern California, 1948.

Material *	Pounds
Pyrethrum (all forms)	25,000
Rotenone	50,000
Nicotine (base or sulfate)	50,000
Lead arsenate	750,000
Calcium arsenate	250,000
Sulfur	20,000,000
Lime sulfur	500,000 (gallons)
Fluorine compounds	200,000
DDT, tech.	1,000,000
DDD	200,000
Hexachlorocyclohexane, 12 percent gamma isomer	250,000
Hexachlorocyclohexane, 99 percent (lindane)	Experimental
Chlordane	50,000
Toxaphene	50,000
TEPP	100,000
Parathion (thiophos)	Experimental
Spray oils	2,500,000 (gallons)
Copper compounds	1,000,000
Mercury compounds	10,000
Ethylene dibromide	250,000
Dichloropropane-dichloropropene mixture	150,000
2,4-D	50,000
Trichloro-acetic acid	----------
Other herbicides	----------

* All quantities are for concentrated form except where indicated.

RUBBER

Though the western rubber industry is usually thought of as concentrated largely in southern California, there are a few medium sized manufacturers in the San Francisco Bay area. We have an aggressive tire manufacturer, one of the largest producers of camelback, a tile manufacturer, and at least seven manufacturers of mechanical rubber goods. Raw material requirements are impressive and are estimated to include:

Raw materials	Pounds per year
Rubber	
GR-S	8,500,000
Natural	6,500,000
Latex	150,000
Neoprene (and other synthetics)	750,000
Accelerators	
(All types)	160,000
Antioxidants	
(All types)	110,000
Plasticizers, Softeners, and Tackifiers	
Process oils	750,000
All others	50,000
Miscellaneous	
Sulfur	400,000
Carbon black	6,000,000
Zinc oxide	750,000
Stearic acid	180,000

PHARMACEUTICAL MANUFACTURING AND PROCESSING

The chemical requirements of the pharmaceutical manufacturing and processing industry are characteristically diverse. The wide variety of small volume end-products gives a raw material list more impressive for length than for tonnage. We have attempted to divide a partial list of the chemicals consumed into three categories:

Over 100,000 pounds per year	25,000-100,000 pounds per year	Under 25,000 pounds per year
Phosphoric acid	Phenylacetic acid	Butanol
Caustic soda	Acetone	Octadecanol
Dextrose	Ethylene glycol	Mono-potassium phosphate
Lactose	Misc. natural oils	Sodium acetate
Sucrose	Calcium carbonate	Sodium sulfate
Amyl acetate (mixed)	Sodium chloride	Procaine hydrochloride
Lard oil	Mono-sodium phosphate	Glycerine
Filter aids	Diphenylamine	Many others
Ethanol	Formaldehyde	

EXPLOSIVES

The total dynamite production in northern California is about 50,000,000 pounds a year or roughly 40 percent of the total produced on the west coast.

There are in the area two large producers of nitroglycerine base dynamite and one large manufacturer of dynamite based on nitrostarch. One of the former companies produces black-powder and also operates chemical plants for the production of ammonia, nitric acid, and ammonium nitrate. The nitric acid and ammonium nitrate facilities are adequate to take care of the mixed acid and ammonium nitrate requirements of all three plants. Spent acid (sulfuric) is returned to the manufacturer for fortification or sold to the fertilizer manufacturing industry. For simplicity we will consider the industry on the basis of chemicals consumed rather than chemicals purchased. The black-powder raw material requirements are omitted. Estimated total chemical consumption in production of dynamite is as follows:

Chemical consumption in production of dynamite	Pounds per year
Glycerine	2,500,000
Ethylene glycol	2,000,000
Cornstarch	3,250,000
Mixed acid	25,000,000
Ammonium nitrate	16,000,000
Sodium nitrate	15,000,000
Dinitrotoluene (oil)	650,000
Nitrocellulose	200,000
Zinc oxide	30,000
Aluminum (powder)	300,000
Aqua ammonia (20 percent)	1,100,000
Fillers:	
Diatomaceous earth	Almond shell meal
Sawdust	Wood flour
Apricot pit meal	Potato starch
Corncob meal	

INDUSTRIAL CLEANING

The industrial cleaning field as a whole comprises a market of considerable magnitude. We will briefly discuss several subdivisions in this group but do not have coverage of the entire industry.

Airline Operation and Maintenance. The location of the United Air Lines maintenance base at South San Francisco is the principal contributing factor in the total chemical requirements for this industry. Since many of the products used are compounded materials, a specific breakdown on a poundage basis is difficult. On a dollar basis the total requirements are over $100,000 a year, from which we have estimated the following breakdown:

Chemicals used in airline operation and maintenance	Pounds per year
Solvents	600,000
Chemical cleaners	250,000
Isopropanol	250,000
Methanol	125,000
Specialty products and proprietary items	25,000

Industrial Degreasing. It is estimated that industrial degreasing operations in northern California consume approximately 2,500,000 pounds of trichloroethylene and 150,000 pounds of perchloroethylene annually.

Dry Cleaning. In the dry cleaning industry a variety of specialty products are used along with a relatively large volume of petroleum solvents. We have attempted to estimate only the chemical solvents and suggest that the annual northern California consumption amounts to approximately 3,000,000 pounds of perchloroethylene and 1,750,000 pounds of carbon tetrachloride.

Commercial Laundries. The commercial laundries in northern California do an annual business of over $30,000,000 per year. Purchases of wash-room chemicals run about $1,200,000 annually. The specific requirements are estimated to include:

Chemicals used by commercial laundries	Pounds per year
Soap (and synthetics)	3,500,000
Alkaline builders	7,500,000
Bleach (20 percent)	300,000 *
Blueing (dry basis)	2,000
Sour	550,000
Starch	--------------

* Gallons.

The use of synthetic detergents, particularly in compounds with builders, in commercial laundry operation is on the increase, but at the present time represents only a small portion of the total. The ratio of alkaline products to soap used has also increased materially from pre-war practice. Caustic soda is the principal alkali used with silicates, causticized silicates are second, and soda ash is third in importance. Bluing is difficult to estimate due to the tremendous difference in the amount required of the various types. Our figure has been converted to the concentrated ''Zanzibar Blue'' type.

FOOD PROCESSING

The food processing industry is large in the northern California industrial picture. A fairly large volume of chemicals is utilized and the list is certainly diverse. Some statistics have been available on a national basis and a paper on the subject *Chemicals in the Food Industry* was prepared by Dr. T. L. Swenson in 1947.[2]

The food industry is one industry where national statistics do not give good indications of regional usages. Stanford Research Institute made a study of chemicals used in food processing and developed a list of over 1,400 items. They concluded that information regarding the quantities utilized in any given area could be obtained only by a comprehensive survey.

To give an idea of the volumes involved—it is estimated that per year in northern California, food processing consumes 13,000,000 pounds of salt, 4,000,000 pounds of sulfur, and 3,000,000 pounds of caustic soda. The wide use of food supplements and vitamins, flavoring and preserving agents, and stabilizers leads to high dollar volume and an attractive market.

SUMMARY

Since the report is not comprehensive and does not cover such major items as general inorganic and organic chemical manufacturing, it cannot sum up a meaningful regional total for any specific chemical. Also, it should be noted that a very limited number of items are consumed by more than one or two industries. The items of general consumption include the heavy chemicals—salt, caustic soda, chlorine, sulfuric acid—and a few organic chemicals.

As an example glycerine in northern California totals almost 5,000,000 pounds a year in the resins and explosives industries, glycol about 2,200,000 in the same fields, phenol amounts to approximately 5,000,000 pounds a year if resins and petroleum refining are totaled. Going back to the heavy chemicals, it is safe to say that yearly caustic soda consumption in northern California probably totals over 100,000,000 pounds and sulfuric acid over 300,000,000 pounds. These totals are still not all inclusive and are probably exceptions; however, they do serve as aids in assessing the magnitude of the area's chemical requirements.

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[2] Presented at the conference on Western Chemical Markets before the Western Chemical Market Research Group at the Pacific Chemical Exposition, October 21, 1947.

SKAGGS SPRINGS QUICKSILVER MINE, SONOMA COUNTY, CALIFORNIA *

By Donald L. Everhart **

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ABSTRACT

The Skaggs Springs quicksilver mine is 33 miles from the Pacific Ocean in Sonoma County, California. It is accessible by 15 miles of paved road from the town of Healdsburg, which lies to the southeast. In the period between the discovery of the ore deposits in 1928 and the closing of the mine in 1944, 330 flasks of quicksilver were produced, with the peak of production in 1941 and 1942.

The mine workings, totaling 1,825 feet in length, lie within a block of interbedded sandstone and shale of Cretaceous (?) age that is bounded by two northwest-trending faults separating it from rocks of the Franciscan group of Upper Jurassic (?) age. These older rocks include sandstone and a little shale, greenstone, and mica, chlorite, and amphibole schists.

Several hot springs occur in the younger sedimentary rocks along faults that appear to have formed part of the structural control for the quicksilver deposit.

Metacinnabar, associated with the yellow crystalline hydrocarbon, curtisite, is finely disseminated through the Cretaceous (?) sandstone, and is the chief ore mineral of the deposit. Less commonly, the sandstone is impregnated with small cinnabar grains.

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* Published by permission of the Director, U. S. Geological Survey.
** Geologist, U. S. Department of the Interior, Geological Survey.

The ore minerals are concentrated in a massive sandstone bed beneath a hanging-wall contact with conformably interbedded, fine-grained, relatively impervious shale and sandstone. Northwest-striking, southwest-dipping faults cut the sandstone and shale beds and are in turn cut or offset by later east-striking, gently north-dipping fractures and faults that cause local flattening of the hanging wall. These two fault groups and the impervious shale capping constitute the main structural control of the ore shoots.

The ore mined thus far at Skaggs Springs has yielded an average of about 3 pounds of quicksilver per ton, but the grade of ore must be materially increased by more selective mining if production is to be carried on at a profit, even with high prices.

INTRODUCTION

Location

The Skaggs Springs quicksilver mine, also known as the Star Springs mine, is in the California Coast Range in the north-central part of Sonoma County (fig. 1). The property includes parts of secs. 23, 24, and 26, T. 10 N., R. 11 W., M. D., the mine itself is at an altitude of about 400 feet above sea level in a small valley about a quarter of a mile south of the Skaggs Springs hotel and resort (pl. 66). The hotel is 33 miles from the coast, and good paved roads lead from it to the towns of Cloverdale, 12 miles to the north, and Healdsburg, 15 miles to the southeast.

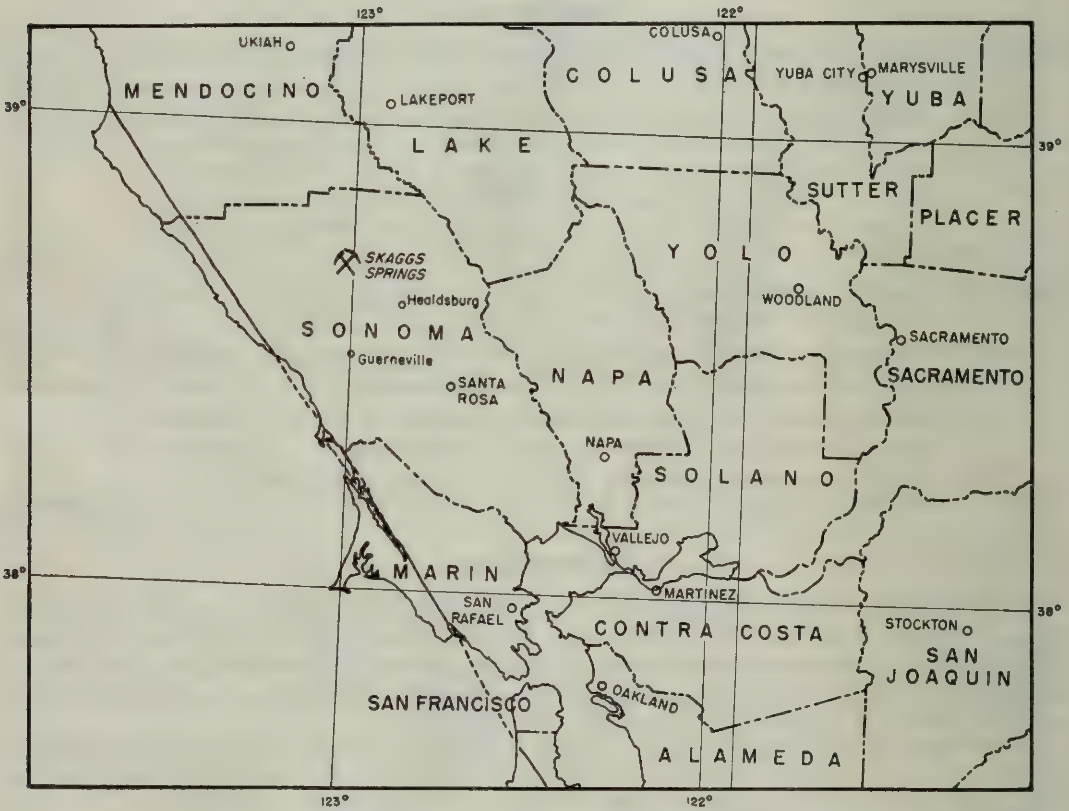
123°
122°
UKIAH
COLUSA
MENDOCINO
COLUSA
YUBA CITY
MARYSVILLE
YUBA
39°
LAKEPORT
LAKE
39°
SUTTER
PLACER
SKAGGS SPRINGS
YOLO
Healdsburg
WOODLAND
SONOMA
SACRAMENTO
SACRAMENTO
Guerneville
SANTA ROSA
NAPA
NAPA
SOLANO
VALLEJO
38°
MARIN
MARTINEZ
SAN RAFAEL
38°
CONTRA COSTA
STOCKTON
SAN JOAQUIN
OAKLAND
SAN FRANCISCO
ALAMEDA
123°
122°

FIGURE 1. Index map of part of central California, showing the location of Skaggs Springs.

The topography around Skaggs Springs is moderately rugged with relief of about 1,700 feet. The mountains are heavily timbered with conifers and oaks, and the valleys, such as those in which the hotel and the mine are located, are open meadowlands.

History, Ownership, and Production

The quicksilver deposits at Skaggs Springs were discovered, somewhat by accident, in 1928.[1] According to Ransome and Kellogg [2] "Quicksilver ore was first noted as occurring in commercial quantities on this property in 1925." Mr. Curtis collected specimens of an unfamiliar yellow mineral from fractures in the sandstone outcrops along the creek near the resort, and sent them to the Carnegie Institution of Washington for identification. The Institution reported the yellow crystals to be a new hydrocarbon mineral, subsequently named curtisite for the discoverer, and also reported that the specimens contained a considerable amount of metacinnabar.

The sandstone containing the finely disseminated matacinnabar and curtisite was mined throughout the next 10 years, and during a 90-day period in 1934 Mr. Curtis recovered 42 flasks of quicksilver with the use of a small retort. During the late 1930's, under the supervision of the late Charles Cavagnero, ore from part of the upper workings of the present mine was extracted and yielded nine flasks of quicksilver. The mining operations were taken over in October 1940 by Star Springs Mercury, Inc., of Hollywood. This company expanded the workings of the mine to the extent mapped in this investigation, and produced about 250 flasks. A reduction plant with a daily capacity of 20 tons was erected in June 1941, and production from it began in September 1941 and continued until September 1942 when Star Springs Mercury, Inc., was liquidated.

The mining property was leased in January 1943 by Mr. Edward J. Bumstead of Skaggs Springs, who began operations early in February 1943. An extensive program of sampling and assaying was undertaken as a guide to further development, and as a result an additional 30 flasks of quicksilver was produced before the mine was closed in 1944.

The total production of the mine has been approximately 330 flasks.

Field Work and Acknowledgments

Mr. W. Bradley Myers and the writer, of the U. S. Geological Survey, spent 4 days during July 1942 mapping the underground workings of the mine on a scale of 1 inch to 10 feet. In February 1943, the writer spent 2 days in similar underground mapping and 2 days in plotting the surface geology of the mine area on an aerial photograph at an approximate scale of 1:20,000. During this investigation, hearty cooperation was given to Mr. Myers and the writer by Mr. Tracey Pierce, mine foreman, and by Mr. Leo Curtis and Mr. E. J. Bumstead of Skaggs Springs.

This study was made as a part of the U. S. Geological Survey's wartime investigation of strategic-mineral deposits. The problems of mineralization and associated hot springs activity should receive much more study before the ore deposits at Skaggs Springs can be fully understood.

GENERAL GEOLOGY

In the Skaggs Springs area the most important geologic feature is a block of sandstones and shales, tentatively considered to be Lower

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[1] Oral communication from Mr. Leo Curtis, proprietor of the hotel and owner of the property.

[2] Ransome, A. L., and Kellogg, J. L., Quicksilver resources of California: California Jour. Mines and Geology, vol. 35, no. 4, p. 469, October 1939.

Cretaceous in age, which has been down-faulted into rocks of the Franciscan group of Upper Jurassic (?) age (pl. 66). The quicksilver mine itself is entirely within the younger sandstone and shale. These rocks are cut by numerous fractures along some of which there has been small displacement. The fractures have acted as important controls in the emplacement of the ore bodies. Much of the area underlain by rocks of the Franciscan group immediately west of the mine is covered by a large landslide, and the Cretaceous (?) sedimentary rocks in the vicinity of Skaggs Springs are covered extensively by alluvium.

The rocks of the Franciscan group, which border the Cretaceous (?) rocks on two sides in the vicinity of the mine, are mostly massive, medium- to coarse-grained arkosic sandstone. This sandstone is altered and is greenish-brown. The alteration, lack of regular bedding, and massive character of the sandstone in the Franciscan group distinguish it from the Cretaceous (?) sandstone. Small bodies of massive chert and of greenstone, and lenses of mica, chlorite, and amphibolite schist have been mapped in the Franciscan group. Serpentine, found in many Coast Range quicksilver districts, was not observed in place within the mapped area, although a few pieces of serpentine float were found in the landslide west of the mine.

The Cretaceous (?) rocks can be divided into at least three units in the immediate vicinity of the mine. The uppermost and lowermost are lithologically similar, and consist of interbedded, fine-grained, light-gray sandstone and very fine-grained dark-gray shale in beds as much as 4 inches in thickness. The middle unit consists of medium-grained, light-gray, massive sandstone beds. At least 80 percent of the sandstone is rounded and frosted quartz grains; oligoclase grains, which are rather thoroughly sericitized, make up 10 to 15 percent of the rock. In the immediate vicinity of the mine, the quartz and feldspar grains are cemented by opal.

The beds of Cretaceous (?) sedimentary rocks have a general strike of N. 65°-75° E. They dip 50°-70° SE. in the lower mine levels, but in the upper levels are considerably flatter. Northwest of the mine, near the western boundary fault of the Cretaceous (?) rocks, the strikes are more westward, turning in a few places to a slightly northwest direction. Across the valley to the east, the beds strike northeast and dip 40°-50° SE.

Faults that bound the area underlain by the Cretaceous (?) sedimentary rocks enclose a block 950 to 1,600 feet wide, which trends northwestward. The southwest boundary appears to be a straight-line fault contact with the massive, moderately altered sandstone of the Franciscan group. The fault, which is covered by the above-mentioned landslide for a distance of at least 1,000 feet just southwest of the mine, strikes N. 35° W. The northeast boundary of the Cretaceous (?) band of rocks is a nearly parallel but curving fault that strikes N. 25°-65° W. To the northwest the strike becomes more northward.

Although no fossils have been found in the younger sediments of this band, Stalder[3] has correlated these rocks with his Walker Ridge sandstone and shale of the Rainbow series, which he tentatively has designated as post Franciscan and older than upper Miocene[4] in age. This correlation was made solely on general lithologic characteristics, but in this report the age determination is assumed to be correct.

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[3] Stalder, Walter, Preliminary reconnaissance report on the oil possibilities in the vicinity of Skaggs Springs, Sonoma County, California: Unpublished private report, p. 2, November 1922, San Francisco, California.

[4] Stalder, Walter, Humboldt County: California Min. Bur. Bull. 69, p. 449, 1914.

The large landslide covers much of the northeast slope of the high ridge to the west of the mine. Typical hummocky topography characterizes the slope, none of the rocks appear to be in place, and the relatively sparse timber may indicate that the mass beneath was moving in 1943. Two cliffs, about 40 feet and 70 feet high, along the southwest side of the fault west of the mine, may be part of a poorly defined fault scarp. The oversteepening of the slope by continued upthrow of the southwest side of the fault may have caused the landslide.

SKAGGS SPRINGS QUICKSILVER MINE

Workings

The Skaggs Springs quicksilver mine, with 1,825 feet of workings, has five levels and three main raise stopes, and extends to a depth of 135 feet below the collar of the inclined shaft (pl. 67). The main entry to the mine is a shaft inclined at a slope of 38°. This shaft develops the mine to a vertical depth of 100 feet. Levels have been driven from the shaft at depths of 16, 50, 73, and 100 feet (pl. 68). A winze from the 100-foot level connects with the 135-foot level. Raise stopes have been mined from the 50-foot level to the 16-foot level, from the 100-foot level to the 50-foot level, and from the 135-foot level to the 100-foot level (pl. 68). These raise stopes are larger than ordinary raises in most mining districts but are smaller than most stopes. They do not exceed 20 feet in height or width, and the stope lengths are 75, 180, and 45 feet respectively, between the three lower levels. In general the raise stope outlines are irregular, although the shapes are roughly pipelike.

A bulldozed prospect pit, about 40 feet in diameter and 10 feet in maximum depth, explores mineralized sandstone about 300 feet northwest of the collar of the inclined shaft.

Geology of the Mine

A massive ore-bearing sandstone 50 to 60 feet thick, which strikes about N. 65°-75° E. and dips about 55° SE., contains a large proportion of the workings of the Skaggs Springs mine. The hanging wall of the deposit is formed by interbedded shales and sandstones that conformably overlie the thick ore-bearing sandstone. The footwall, which is exposed only on the 73 and 100-foot levels, and in the shaft from a depth of 55 feet to its base, is similarly interbedded shales and sandstones that lie conformably below the ore bed.

Mineralization

Numerous fractures, joints, and faults with small offsets, which cut the hard, massive sandstone bed, have been open to ascending solutions that, in structurally favorable places, have partly filled the fractures and formed veins. Most common of the minerals filling the fractures is hard, dark opal that is locally mixed with fine-grained quartz and chalcedony, similar to the material that cements the sandstone. The opaline veins are cut by later fractures that in places are filled with bright greenish-yellow, crystalline curtisite (probably $C_{24}H_{18}$).[5] Realgar (AsS) and orpiment

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[5] Dana, E. S., A textbook of mineralogy, 4th ed., p. 776, New York, John Wiley and Sons, Inc., 1932.

(As_2S_3), the red and yellow sulfides of arsenic, are the other two chief non-ore vein minerals in the Skaggs Springs mine. Metacinnabar, the black mercuric sulfide, is the principal ore mineral, and occurs in veins and more abundantly in minute isometric grains disseminated through the massive sandstone near the hanging wall. Cinnabar, though present in the mine, is so rare as to be a minor ore mineral.

Metacinnabar. The mode of occurrence of the metacinnabar has led to great difficulty in mining, for it is hard to recognize the mineral in the rock and virtually impossible to estimate the content. The metacinnabar-bearing veins, which locally are half an inch thick, almost invariably contain some curtisite, which is considered to be a guide to ore. Unfortunately, however, most of the ore taken from the mine has not contained well-defined veins of metacinnabar, but has consisted of fractured sandstone that contains disseminated metacinnabar. These black metacinnabar grains in the gray sandstone are extremely difficult to distinguish from small blobs of nearly black opal and other dark constituents of the sandstone. Underground it is almost impossible to distinguish between ore and ''waste'' because the appearance of the two is identical.

Cinnabar. The cinnabar in the mine occurs as fine-grained impregnations, which color the rock a pale pink, adjacent to small fractures in both the massive ore-bearing sandstone and the sandstone of the hanging wall. Most of these impregnations occur on the 100-foot level, and although cinnabar was noted as far as 35 feet below the hanging wall, nearly all of it is much closer to the contact. The small fractures that cut the cinnabar-bearing rock are commonly filled with curtisite, but as no metacinnabar has been observed in direct association with cinnabar, the relationship between the two ore minerals is not known.

Curtisite. The curtisite veins are nowhere more than 0.2 inch thick, and they pinch out in the plane of the vein within 3 or 4 feet in all directions. In many places, slickensided surfaces of small faults are coated with curtisite, and with it are other dark-brown to black, pitchy, amorphous hydrocarbons. The greatest concentrations of hydrocarbons, especially curtisite, are near the hanging wall in the raise stopes between the 50 and 100-foot levels and the 16 and 50-foot levels. Some curtisite is found on all the levels except the 135-foot level, but it is nowhere more than a few feet from the hanging wall.

Realgar and Orpiment. Realgar is much more widespread than orpiment in the Skaggs Springs mine, but neither is abundant except locally on the 135-foot level at and near the hanging wall. Along the creek 250 to 600 feet northwest of the shaft collar, however, much realgar is being deposited, together with metacinnabar, as irregular masses in open spaces along the siliceous veins around the five hot springs.

Structural Control

At the Skaggs Springs mine, deposition of the ore was controlled partly by differences in lithology of the host rocks and partly by certain fractures and fracture intersections.

The lithologic control was exerted by interbedded shale and fine-grained sandstone that overlie porous massive sandstone. The shale beds have acted effectively as a relatively impervious cap to solutions that ascended through the porous sandstone below; all the ore in the mine is found in the porous sandstone just beneath the shale beds.

The faults and fractures that controlled the ore deposition can be divided roughly into three sets. All of them apparently occur largely within the sandstone, and are considered to have provided conduits for ore solutions ascending to the hanging-wall contact. The oldest set is a series of northwest-striking, southwest-dipping faults thought to be related to the southwest boundary fault of the Cretaceous (?) rocks and the Franciscan group. Locally, metacinnabar and cinnabar occur along and near these faults, and curtisite more generally is distributed adjacent to them. In the extreme south corner of the 100-foot level, where one of the faults of this oldest group intersects the hanging-wall contact, there are local concentrations of ore, and large quantities of cold water and bubbles of methane rise into the floor of the drift along the fault. The localized ore concentrations and the gas and water emanations are evidence that the fault acts and has acted as conduit for solutions.

A second smaller and less important group of faults mapped in the mine strikes N. 15°-55° W., but dips gently northeast, and is younger than the northwest-trending, southwest-dipping faults described above. The intersection of one of these younger faults, which is exposed in the raise stope between the 100-foot level and the 135-foot level, with the hanging-wall contact and a fault of the first group is the apparent control for the high-grade ore shoot mined in the raise stope. (See pl. 69, section BB′). Other smaller faults of this group are exposed on all levels except the 73-foot level, but have negligible offsets, and seem to have played little or no part in the control of the ore deposits.

The youngest, and perhaps economically most important, fault group is made up of east-striking, gently north-dipping fractures that are numerous throughout all levels and stopes in the mine. The faults of this group are highly irregular in attitude, and tend to split into many branching fractures. These faults are not all contemporaneous, but because of their complicated relations they have not been subdivided. In some places, steeper faults of the group seem to be cut off by later, flatter faults, but in other places, steep and flat faults intersect with no apparent offset on either fault. Offsets are generally small, ranging from a few inches to 5 feet. Some of the well-exposed flat faults in the large raise stope between the 50-foot level and the 100-foot level, however, have apparent offsets whereby the lower part of the hanging-wall contact has been displaced a total distance of nearly 55 feet to the southeast. The effect of these gently north-dipping faults is best shown in cross section A-A′ (pl. 69), which longitudinally bisects the large raise stope. The hanging wall flattens markedly between the 50 and 100-foot levels, and in this distance the stopes are bunched beneath the flattest parts. The same flattening is shown in cross section B-B′ (pl. 69). A large part of the ore taken from the mine has come from the stoped areas shown in cross section A-A′; curtisite is more abundant here than in any other part of the mine. This particular part of the hanging wall, which is abnormally flattened by faulting, therefore, apparently is the most effective structural trap in the deposit. Other flat, or nearly flat, parts of the hanging wall have been almost as productive.

The surface expression of the faults observed underground is not clear. Only two of the faults of the first group described can be found at the surface. A prospect pit that is about 300 feet N. 60° W. from the inclined shaft collar has been dug in the soft, altered sandstone and shale underlying the slope. The material from this pit contains considerable quantities of extremely fine-grained metacinnabar and averages about 4 pounds of quicksilver to the ton. The mineralized area is approximately on the projected strike of a fault of the oldest set exposed underground, and the solutions that deposited the metacinnabar at the surface probably rose along this large fracture, or along fractures splitting from it. Second, the strongly sheared zone exposed in the extreme northeast corner of the 100-foot level (pl. 68) may be connected with the surface. Projected upward and northwestward along its dip and strike, the zone approximately lines up with the group of hot springs that are along the creek northwest of the mine, and may be part of a fault that may serve as a conduit for the hot springs.

Summary

The succession of events that immediately effected the formation of the quicksilver ore deposits at Skaggs Springs may be summarized as follows: Hydrothermal, silica-rich solutions rose along several sets of faults, filling the adjacent minor fractures in the sandstone with opal. For example, vein filling by opal has been especially active near the hot springs that occur along one of the northwest-trending faults that cut the rocks of Cretaceous (?) age. Later solutions deposited arsenic sulfides; hydrocarbons, especially curtisite; and metacinnabar and minor amounts of cinnabar. The highest concentrations of the hydrocarbons and the quicksilver minerals occur in the permeable sandstone where the conduits from below brought the solutions into the structural traps formed by the fault-flattened parts of the hanging-wall contact.

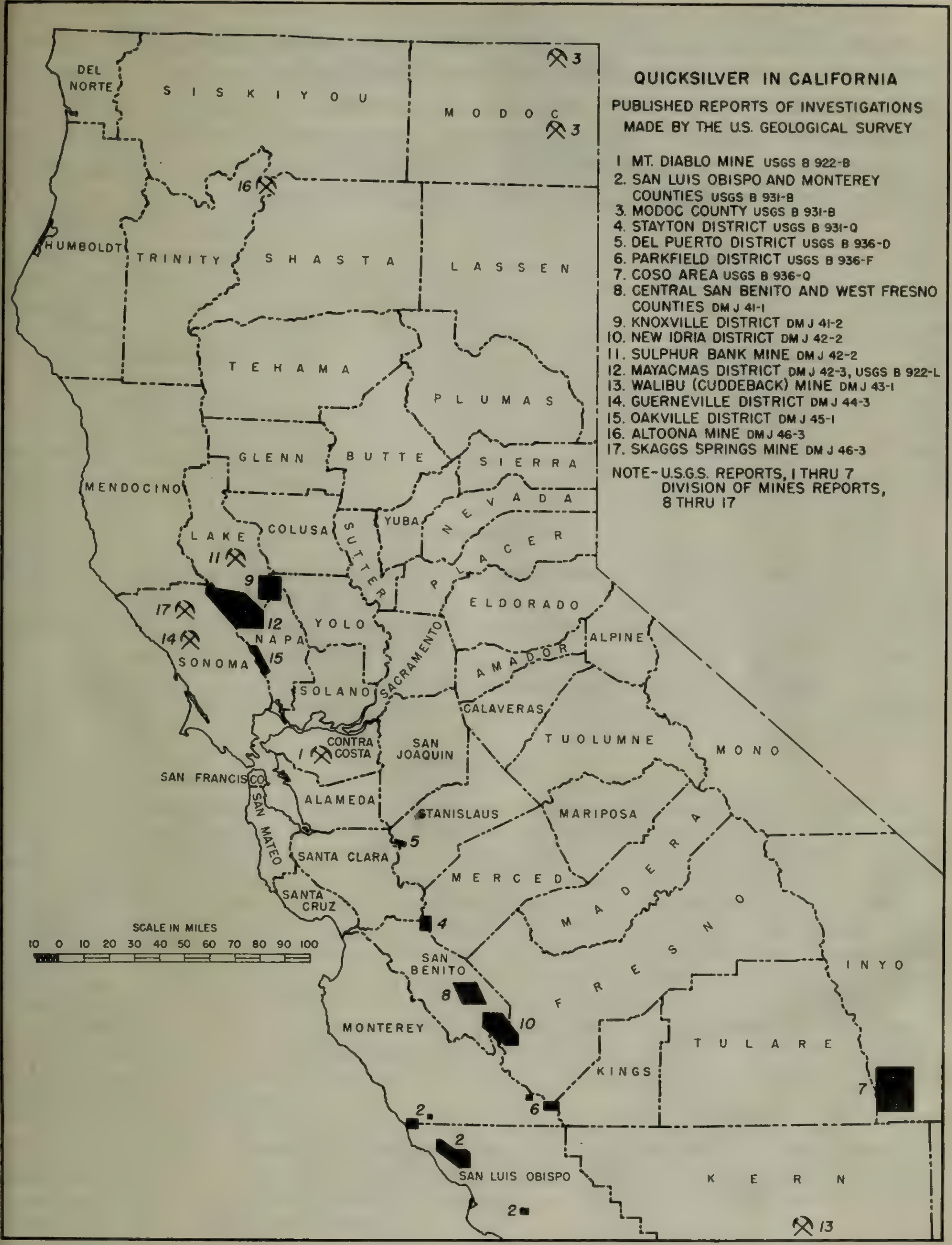
GRADE OF ORE

Reliable figures on the grade of ore that has been taken from the Skaggs Springs mine have been recorded only by Star Springs Mercury, Inc., during the 13 months of production from the rotary furnace. From the first of September 1941 through September 1942, approximately 5,500 tons of ore were treated, yielding 3.08 pounds of quicksilver per ton. Assays and the retorting of small tonnages of ore during this period, however, resulted in slightly higher yields to a maximum of 3.37 pounds per ton.

Mr. E. J. Bumstead took over the property in 1943 with the hope that careful sampling throughout the mine would enable him to mine more selectively than had been done before, thereby materially increasing the grade of ore actually treated, but this hope was not realized. The high degree of dissemination of the fine-grained metacinnabar in the sandstone, as pointed out in the discussion of the ore deposits, has defied estimation of grade in the past. The abundance of associated curtisite, commonly used in this mine as a guide to ore, is not necessarily a reliable criterion.

SUGGESTIONS FOR FURTHER DEVELOPMENT

Future exploration in the Skaggs Springs mine should follow the hanging-wall contact westward from the present workings to the boundary fault and eastward at least as far as the northwest-trending fault


QUICKSILVER IN CALIFORNIA
PUBLISHED REPORTS OF INVESTIGATIONS MADE BY THE U.S. GEOLOGICAL SURVEY
1 MT. DIABLO MINE USGS B 922-B
2. SAN LUIS OBISPO AND MONTEREY COUNTIES USGS B 931-B
3. MODOC COUNTY USGS B 931-B
4. STAYTON DISTRICT USGS B 931-Q
5. DEL PUERTO DISTRICT USGS B 936-D
6. PARKFIELD DISTRICT USGS B 936-F
7. COSO AREA USGS B 936-Q
8. CENTRAL SAN BENITO AND WEST FRESNO COUNTIES DM J 41-1
9. KNOXVILLE DISTRICT DM J 41-2
10. NEW IDRIA DISTRICT DM J 42-2
11. SULPHUR BANK MINE DM J 42-2
12. MAYACMAS DISTRICT DM J 42-3, USGS B 922-L
13. WALIBU (CUDDEBACK) MINE DM J 43-1
14. GUERNEVILLE DISTRICT DM J 44-3
15. OAKVILLE DISTRICT DM J 45-1
16. ALTOONA MINE DM J 46-3
17. SKAGGS SPRINGS MINE DM J 46-3
NOTE-U.S.G.S. REPORTS, 1 THRU 7 DIVISION OF MINES REPORTS, 8 THRU 17
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
LASSEN
TEHAMA
PLUMAS
GLENN
BUTTE
SIERRA
MENDOCINO
NEVADA
YUBA
LAKE
COLUSA
SUTTER
PLACER
ELDORADO
YOLO
NAPA
SONOMA
SACRAMENTO
ALPINE
AMADOR
SOLANO
CALAVERAS
TUOLUMNE
MONO
CONTRA COSTA
SAN JOAQUIN
SAN FRANCISCO
SAN MATEO
ALAMEDA
STANISLAUS
MARIPOSA
SANTA CLARA
MERCED
MADERA
SANTA CRUZ
SAN BENITO
FRESNO
INYO
MONTEREY
TULARE
KINGS
SAN LUIS OBISPO
KERN
SCALE IN MILES
10 0 10 20 30 40 50 60 70 80 90 100
1
2
3
4
5
6
7
8
9
10
11
12
13
14
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16
17

FIGURE 2. Index map of California quicksilver mining districts and mines on which reports have been published by the United States Geological Survey and the Division of Mines. These reports are the results of geological work by the United States Geological Survey in World War II strategic minerals investigations.

zone exposed on the 100-foot level. Those levels where the effective hanging wall is flattened by north-dipping flat faults should be especially explored. In addition, the necessary amount of prospecting should be carried through the fault zone to the northeast to determine definitely the eastern terminaiton of the ore deposits.

Two ore bodies exposed on the surface, one in the bulldozed pit and one in the creek bottom below the ore bins, should be developed and followed at depth.

In this mine, it is all-important to employ accurate methods for distinguishing ore that yields considerably more than 4 pounds to the ton from lower-grade ore or waste rock, for in all past operations the over-all grade of the ore has been too low even at high war-time prices. The extensive and rapid sampling and assaying necessary for this may prove too expensive to be justified by the average low-grade ore in the mine, unless a suitable, cheap, simplified procedure is used.

THE ALTOONA QUICKSILVER MINE, TRINITY COUNTY, CALIFORNIA *

By C. Melvin Swinney **

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71. Geologic cross-section and level maps of the Altoona quicksilver mine, Trinity County, California In pocket

ABSTRACT

The Altoona quicksilver mine is in the northeastern part of Trinity County, California, about 12 miles west of Castella. It has yielded, from intermittent operations since its discovery in 1871, more than 33,000 flasks of quicksilver. The deposit is of exceptional interest geologically because it is outside the principal belt of California quicksilver deposits. The ore bodies, in which the economic minerals are cinnabar with a little native mercury, are steeply dipping tabular lenses that average about 5 feet in thickness and locally attain a length and depth of more than 200 feet. The average grade of all the ore that has been mined is about 1 percent mercury, but some ore that contained up to 3 percent mercury is said to have been mined in the late 1890's. The ore in sight at the time the property was examined in 1943-44 averaged about 18 pounds of quicksilver to a ton. It was profitable to mine ore of this grade at the then prevailing price of about $200 a flask (76 pounds of mercury). When the price of mercury dropped in 1945, the mine was closed.

The ore bodies are localized along faults that cut altered diorite, and probably extend into adjacent sheared serpentine. Along the continuation of these ore-bearing faults, undiscovered ore bodies of moderate size probably can be found, but, at a mine as isolated as this one, exploring and mining can be profitable only during a period when a high price for quicksilver is assured.

INTRODUCTION

The Altoona quicksilver mine (fig. 1) is on the East Fork of the Trinity River, in the southern part of the Klamath Mountains, California. It is in sec. 22, T. 38 N., R. 6 W., M. D., in northeastern Trinity County. The shipping point nearest to the mine is Castella, on the Southern Pacific Railroad and on U. S. Highway 99. From Castella the mine is readily reached in the dry season by 24 miles of well-maintained dirt road, but

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* Published by permission of the Director, U. S. Geological Survey.
** Geologist, U. S. Department of the Interior, Geological Survey.

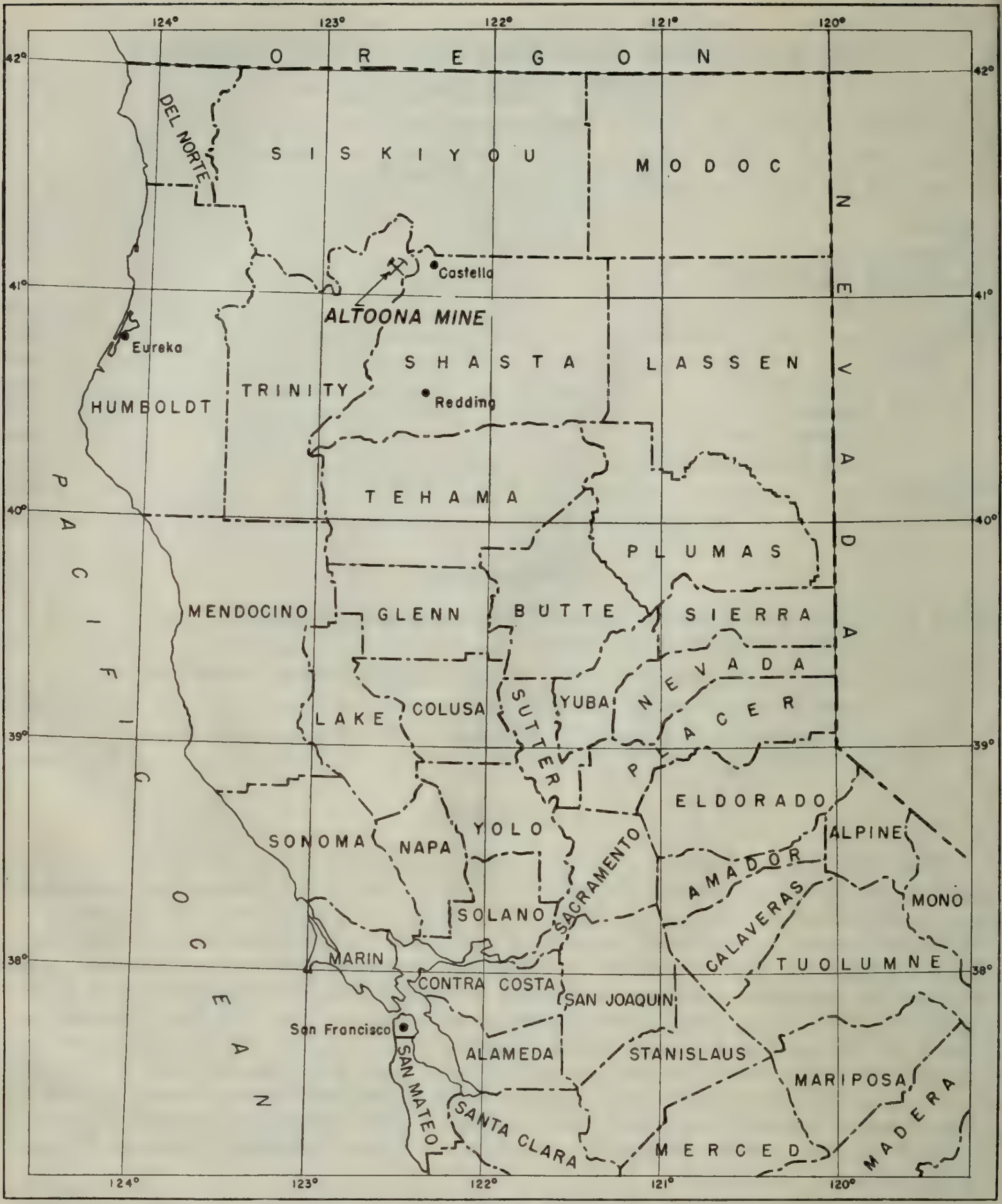
OREGON
PACIFIC OCEAN
NEVADA
ALTOONA MINE
Castella
Eureka
Redding
San Francisco
DEL NORTE
SISKIYOU
MODOC
SHASTA
LASSEN
TRINITY
HUMBOLDT
TEHAMA
PLUMAS
MENDOCINO
GLENN
BUTTE
SIERRA
NEVADA
LAKE
COLUSA
SUTTER
YUBA
PLACER
ELDORADO
SONOMA
NAPA
YOLO
ALPINE
AMADOR
SACRAMENTO
SOLANO
CALAVERAS
MONO
MARIN
TUOLUMNE
CONTRA COSTA
SAN JOAQUIN
ALAMEDA
STANISLAUS
SAN MATEO
MARIPOSA
SANTA CLARA
MERCED
MADERA
124°
123°
122°
121°
120°
42°
41°
40°
39°
38°

FIGURE 1. Index map showing location of the Altoona quicksilver mine, Trinity County, California.

during the wet and snowy winter months the road commonly is blocked for a week or more. The mine is at an elevation of about 4,600 feet above sea level in a region that is rugged and heavily forested. In spite of the strong relief, amounting to nearly 2,500 feet, exposures of bedrock at the surface are rare.

The field work for this report was done as a part of the wartime program of strategic minerals investigations of the U. S. Geological Survey. During September and part of October 1943, the surface and accessible underground workings were mapped, and in May 1944, the area was revisited in order to bring maps of the underground workings up to date. Specimens of the ores and rocks have not been studied in detail in the laboratory.

The writer gratefully acknowledges the friendly assistance of the mine owner, Mr. R. E. Frowenfeld of San Francisco, California, and the mine operators, Mr. C. W. Erickson of San Francisco and the Marsman Company of California. The writer was assisted ably by Philip F. Fix of the Geological Survey during much of the field mapping, and Mr. Fix contributed valuable ideas and suggestions in regard to the geology of the mine. Edgar H. Bailey of the Geological Survey critically read the manuscript and suggested many improvements.

The principal earlier reports dealing with the Altoona mine are by Becker,[1] Forstner,[2] Bradley,[3] and Ransome and Kellogg.[4] These reports show that the inaccessibility of much of the mine workings handicapped these authors as it did the writer.

HISTORY AND PRODUCTION

The first discovery of cinnabar reportedly in place was in 1871 in the area near the site of the present shaft. Until 1875 mining consisted principally of placer operations, the digging of open-cuts, and the driving of a few short adits. In 1875 the Altoona Quicksilver Mining Company, now owned by Mr. R. E. Frowenfeld of San Francisco, acquired the property and as a result of considerable underground exploration found ores which yielded over 7,000 flasks of quicksilver. By 1880 a depth of 132 feet had been reached, and an 800-foot drainage adit had been driven. At that time litigation among the stockholders resulted in a shut down of the mine. To reopen the mine in 1894 the present shaft was sunk to a depth of 450 feet, and soon thereafter a vertical winze was sunk 150 feet below the 450-foot level, making the total depth of the deepest workings 600 feet. Six levels were eventually driven from the shaft and two from the vertical winze. The period from 1895 to 1901 witnessed the greatest development and production of the Altoona mine, for during that interval the operators recovered 19,673 flasks of quicksilver, almost two-thirds of the total production at the time this report was prepared.

The mine was closed down and inaccessible for much of the time between 1901 and 1929, though sporadic work by lessees, principally the reworking of the old dumps, yielded a little quicksilver nearly every year. In 1929 the workings were reopened to the 132-foot level, and some mining continued until 1943, mostly on two new levels, the 50-foot and 100-foot levels. An attempt to unwater the mine below the 132-foot drainage level was begun in 1943, but in May 1944 the mine had been unwatered only to the 350-foot (Trinity) level. With the subsequent drop in the price of quicksilver, operations were curtailed in 1944 and the mine was shut down in 1945.

As the foregoing history shows, the Altoona mine has had only two periods of major operation, 1875-1880 and 1895-1901, and production during these two periods accounts for 27,200 flasks of the total of 33,820 flasks that the mine has yielded. The recovery of an estimated 240 flasks for 1890 was probably from the mine dumps or from placer material below the mine area. During the year 1890 production from the Altoona mine area was about 20 flasks a month.[5] In the years since 1901, mining activity was by lessees and the annual production was slight. At the time the mine was visited in 1944, the Marsman Company of San Francisco was the operator, and production had been increased to about 100 flasks a month.

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[1] Becker, G. F., Geology of the quicksilver deposits of the Pacific slope: U. S. Geol. Survey Mon. 13, pp. 366-367, 1888.

[2] Forstner, William, The quicksilver resources of California: California Min. Bur. Bull. 27, pp. 192-193, 1903.

[3] Bradley, W. W., Quicksilver resources of California: California Min. Bur. Bull. 78, p. 200, 1918.

[4] Ransome, A. L., and Kellogg, J. L., Quicksilver resources of California: California Jour. Mines and Geol., vol. 35, no. 4, pp. 473-474, 1939.

MINE WORKINGS

The underground workings of the Altoona mine total about 10,000 feet in length and extend to a depth of 600 feet, as shown in the composite map of the underground workings, plate 70. A two-compartment vertical shaft extends down to the 450-foot level (Frowenfeld level). A total of eight levels connect with this shaft and a vertical winze, 150 feet deep, connects the 500-foot (Porter) level and 600-foot (Virginia) level with the Frowenfeld level. Only one level, the 132-foot (Castella) level, has any other access to the surface and this opening is through the drainage adit, 885 feet long, which extends southeastward from the shaft.

Only 2,500 feet of workings, including the Castella drainage adit, were accessible at the time the writer examined the mine in 1943. The 350-foot (Trinity) level had been drained by the time the mine was revisited in 1944, but it could not be examined because of lack of ventilation. Plate 70, showing the workings of the Altoona mine, is a modification of an early company map with recent accessible underground workings added. The company maps did not show any geology or stopes on the various levels, but did indicate the general positions of ''veins'' (faults) on those levels. Knowledge of the mine below the Trinity level is scanty.

The mine, at the time of the writer's visits, was equipped for small-scale underground mining operations and had a 1½- by 42-foot oil-burning rotary furnace designed to handle 20 to 30 tons of ore per day. The electric deep-well pump that had been installed to unwater the workings below the Castella level easily handled up to 500 gallons per minute, even with a 450-foot lift, and was entirely adequate for the job, as it was estimated that the workings of the mine filled with water at an average rate of 200 gallons per minute. In addition, the mine had an electrically driven hoist, a blower and ventilating system, and an electrically operated air compressor. Ore cars, hoisted to the surface, were trammed by hand to either an ore bin, or to a waste dump. From the bin the ore was loaded into another car and trammed by hand to the furnace, a procedure requiring considerable handling of the ore.

GEOLOGY

The geology of the Altoona quicksilver deposit is of unusual interest because the deposit lies outside the well-defined major quicksilver belt of the California Coast Ranges. The Altoona region, which is one of metamorphosed Paleozoic and Mesozoic rocks invaded by ultramafic and later felsic igneous rocks, is geologically similar to the Sierra Nevada region. The Altoona quicksilver deposits, however, are unlike those along the eastern flank of the Sierra Nevada at Coso Hot Springs [6] or those in the southern part near Tehachapi;[7] they are somewhat intermediate in character between the Coast Range deposits and the Sierra Nevada deposits.

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[5] Miller, Wm. P., Trinity County: Calif. Min. Bur. Rept. 10, p. 716, 1890.

[6] Ross, Clyde P., and Yates, Robert G., The Coso quicksilver district, Inyo County, California: U. S. Geol. Survey Bull. 936, pp. 395-416, 1943.

The rocks exposed by the Altoona mine workings are intensely altered porphyritic diorite and serpentinized peridotite; the former probably intrudes the serpentine, but all observed contacts are faulted or sheared. Steeply dipping fault zones, that are defined clearly in the diorite but cannot be followed in the sheared serpentine, served as channels for the ore-forming solutions. The richest ore bodies formed in the fault zones as thin tabular lenses that averaged only 5 feet in thickness. These mineralized faults are always called veins in the district and are referred to as veins in this report. Some ore occurs in carbonate veins that cut the serpentine and the silicified and carbonatized serpentine and diorite which formed locally along the contact between the two rocks.

Rocks

The two major rocks within the area mapped around the Altoona mine are serpentine, which formed from peridotite or local dunite, and diorite. The latter was tentatively divided into two mappable varieties—a porphyritic hornblende diorite and a porphyritic feldspathized diorite. Texturally and mineralogically the two varieties are closely related; they differ chiefly in that one has phenocrysts of green hornblende, whereas the other has prominent phenocrysts of feldspar with minor phenocrysts of hornblende. Another rock type, herein termed ''altered rock,'' is composed of quartz and calcium-magnesium carbonates.

Serpentine

Slickensided serpentine is exposed underground in the mine and also crops out in a few places at the surface. It is a massive dark-green rock which locally is veined with white carbonate, probably ankerite. Thin-sections show that the serpentine is composed largely of antigorite, showing the mesh structure characteristic of replacements of olivine, but also some scattered crystals of both ortho- and clino-pyroxenes were found. Small grains of magnetite tend to outline the mesh structure and also are scattered in irregular patches throughout the serpentine. All the exposures of the serpentine contacts, both on the surface and in the mine workings, are quite poor, and an adequate understanding of the relation between the serpentine and the diorite could not be obtained. Wherever exposed the contacts are clearly faulted, but whether this is true everywhere is not known.

Diorite

The two varieties of diorite, which probably are merely facies of a single intrusive, are described below.

Porphyritic hornblende diorite. Typical specimens of the porphyritic hornblende diorite consist of a green groundmass with dark-green phenocrysts of hornblende. The least altered specimens of this rock show in thin section phenocrysts of dark-green hornblende in a holocrystalline fine-grained groundmass composed principally of andesine (?), green hornblende, and a little quartz. Almost all the rock has been intensely altered, however, as follows:

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[7] Bailey, Edgar H., and Swinney, C. Melvin, Walibu quicksilver mine, Kern County, California: California Jour. Mines and Geol., vol. 43, no. 1, pp. 9-14, 1947.

Feldspar (andesine ?) → albite → sericite
Hornblende → chlorite
Ilmenite → sphene
Apatite → no change

The mineralogical changes are apparently the result of hydrothermal metamorphism.[8] However, considerably more work, both in the laboratory as well as in the field, will be necessary before the nature of the hydrothermal solutions can be established with certainty.

Porphyritic feldspathic diorite.[9] Macroscopically the porphyritic feldspathic diorite consists of euhedral phenocrysts of pale-pink to white feldspar and smaller phenocrysts of dark-green hornblende in a groundmass composed of fine-grained light-colored feldspar and minor amounts of hornblende. Like the porphyritic hornblende diorite, this rock also is altered, especially near the faults where it is soft, easily powdered, light colored, and stained by iron oxides. The light-colored feldspar phenocrysts give the altered rock a mottled appearance that distinguishes it from the hornblende diorite, which has a more uniform color and aspect.

A study of a few thin sections revealed the phenocrysts to be sericitized and argillized orthoclase (?) with carlsbad twinning, and green hornblende which is almost entirely altered to chlorite. The groundmass is a fine-grained intergrowth of plagioclase, green hornblende, and a little quartz. The plagioclase feldspar is altered to albite and sericite, and the quartz is a secondary replacement of some of the feldspar. The porphyritic (feldspathic) diorite as well as the hornblende diorite seems to have been affected by hydrothermal solutions.

Altered Rock

Locally, the serpentine, as well as the two varieties of diorite described above, is replaced by quartz and ankerite. Such replacement took place principally in the rock along the contact between the diorite and serpentine, but in some places extended well into the serpentine. The rock resulting from the replacement is a hard gray-green, fine-grained rock that somewhat resembles the ''silica-carbonate rock'' of the Coast Range quicksilver deposits. The term ''altered rock'' will be used in this report instead of ''silica-carbonate rock'' in order to avoid confusion, because the term ''silica-carbonate rock'' has become intimately associated with the Coast Range quicksilver deposits. Moreover, in the Altoona mine area the altered rock is not the principal host for ore deposition, whereas the silica-carbonate rock of the Coast Range deposits is often the ore-bearing rock.

Geologic Structure

The geologic structure of the accessible part of the mine is relatively simple. Two steeply dipping faults, striking northeast and ranging in dip from 53° NW. to vertical, cut across the diorite, and have served as channels for mineralizing solutions that have deposited cinnabar and some native mercury in a gangue of carbonates, with subordinate barite, pyrite, quartz, and clay minerals. These faults, when they enter the serpentine, are dispersed or absorbed and contain no ore minerals.

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[8] Turner, F. J., Mineralogical and structural evolution of metamorphic rocks: Geol. Soc. America Mem. 30, p. 5, 1948.

[9] The term "feldspathic diorite" is here used to signify a relatively higher proportion of feldspar to amphibole in contrast to the darker, more hornblende-rich facies of the rock.

One variation of the simple faults is worth noting. The No. 2 vein (fault) on the 132-foot (Castella) level, 175 feet southwest of the main shaft (pl. 71), is divided into two ore bodies that are separated by about 15 feet of barren rock. This division probably results from a local splitting of the fault and not an en echelon transfer of displacement from one fault to another. Eastward in the Castella level, north of the shaft, and upward on the 100- and 50-foot levels only one ore body was encountered on this vein.

ORE BODIES

The ore bodies examined in the Altoona mine are steeply dipping tabular lenses that average about 5 feet in thickness and locally attain a length and depth (down the dip) greater than 200 feet. They are distributed along the faults, and, as the cinnabar mineralization did not extend any great distance into the altered wall rock on either side of the fault zone, the ore bodies are invariably narrow.

The ore minerals are cinnabar and subordinate native mercury. The gangue minerals include ankerite, pyrite, barite, quartz, and clay minerals. Most of the stoped areas of the mine were inaccessible and observations, therefore, were restricted to small parts of veins No. 1 and No. 2 between the 50-foot level and the 132-foot (Castella) level. Although the 230-foot (Altoona) level and the 290-foot (Shelton) level were open, most of the stopes on these levels were almost entirely caved or back filled so that they could not be examined. The ore on the mine dumps indicates that two different types of vein material were encountered. One type, which has yielded most of the production, occurs in greatly altered, decomposed, ocherous porphyritic hornblende diorite and feldspathized diorite, where these rocks have been cut by the main faults (veins). The other type consists of cinnabar in veinlets of carbonate in the silicified rock.

The type of ore formed in the diorite was exposed in the accessible parts of the stopes in veins No. 1 and No. 2 on the Castella level. Both of these veins, which are about 10 feet wide on this level, strike northeasterly and dip 60° to 70° NW. The veins consist of sheared and altered ocherous porphyritic diorite, and where mineralized they contain disseminated cinnabar and native mercury. Carbonate veinlets, which also contain cinnabar, branch into the walls at numerous places.

At the time the mine was examined, loose fill in the south stope of vein No. 2 was being drawn into ore cars from the back of the Castella level, 175 feet southwest of the main shaft. Rich virgin ore consisting of small crystals of dark-red cinnabar and a little native mercury disseminated through the soft altered diorite was being stoped underhand from the same location. The ore is soft enough to be mined with a pick, and the grade was estimated at about 20 to 30 pounds of quicksilver per ton. The back fill in the old stope above the Castella level was estimated to average about 10 pounds per ton.

The granulated diorite in the fault zone has been largely replaced by quartz and carbonate, and at a first glance closely resembles a fine-grained sandstone. Examination with a hand lens shows the material in the fault zone (vein), to be a fine-grained, friable, porous aggregate of subangular to angular, light-colored grains of quartz and carbonate loosely bonded by hydrous iron oxides. Thin veinlets of carbonate, shattered in the fault zone but continuous where they extend a short distance into the altered wall rock, are numerous. Small crystals of cinnabar occur in these veinlets and also in the surrounding material.

A considerable quantity of coarsely crystalline light-colored carbonate with small masses of cinnabar scattered through it can be seen on the dumps. Small vugs, lined with crystals of cinnabar and in places containing native mercury, commonly occur in the carbonate. It is not known from what part of the mine this material came. The native mercury is believed to be primary as the faces of the cinnabar crystals are smooth and show no evidence of corrosion.

In addition to veins No. 1 and No. 2, parts of which were accessible, the early company map of the underground workings (pl. 70) shows veins No. 3 and No. 4, as well as a possible fifth vein on the 600-foot (Virginia) level. It is reported locally that veins 1, 2, and 3 were approximately parallel and dipped northwest. The old map, on the contrary, indicates vein No. 3 dipping to the southeast. It has been said that the body of ore mined on the Virginia level was found at the junction of veins No. 1 and No. 2.

The fact that vein No. 1 splits into two separate parts on the Castella level suggests that similar complexity in the faults may exist elsewhere in the mine, although no actual evidence of any other splits was observed in the accessible workings. There is also the possibility that vein No. 4, indicated on the company map as striking about N. 45° W., dip not shown, may be a fault offsetting veins Nos. 1, 2, and 3. If so, it may account for the sharp bend in the ore body shown on the Virginia level.

OUTLOOK

The visible ore reserves of the Altoona mine in 1944 were not great, totaling not more than a few hundred flasks of mercury, but only a small percentage of the total workings along the veins were accessible. To judge the probable future outlook for the mine requires an estimate of the ore remaining, the cost of mining this ore, and the probable price of quicksilver. Based on a consideration of these factors, the writer believes the mine is capable of producing about 200 flasks of mercury per month if the price of quicksilver were maintained for a period of two or more years at about $125 a flask, with mining conditions as they were in 1944.

Mining operations at the Altoona mine are expensive. The mine is far from the main highway and railroad, and the transporting of men, fuel, and equipment involves considerable cost. In addition, during the winter months the road is closed by snow; thus if the mine is to operate all year, the road must be kept open and maintained during the winter. The mine workings below the Castella level must be constantly pumped out, for they fill with water at the rate of about 200 gallons per minute. On the other hand, the mine workings do not require a great deal of timbering, and much of the ore is soft enough to be mined with a pick. The ore from the mine is handled twice before arriving at the furnace. This is an extra expense that could be avoided by a more efficient arrangement of waste dumps, reduction plant, and ore bins.

About 75 percent of the underground workings were flooded from 1901 to 1943 and were not subjected to the small-scale mining operations carried on by lessees on all the levels from the Castella level to the surface. Such small-scale mining produced 280 flasks of mercury in 1943, mostly in the last four months of the year. This production was from areas on and above the Castella level. In January 1944, 224 flasks was recovered from ore mined between the Castella and Altoona levels. Part of this was high-grade virgin ore, but the bulk was back fill from the stopes.

It is believed that the average grade of the ore mined from 1871 to 1901 was about 25 pounds of mercury per ton. This estimate is based on the grade of ore in the old stope back fill and the virgin ore observed during the examination of the mine, as well as on the fact that the cost of supplies during the periods of full scale mining (1871-1880 and 1895-1901) was relatively high because of the isolation of the mine. The constant pumping of the mine was an added high cost. Therefore it seems quite likely that ten-pound ore was considered too low in grade to mine between 1871 and 1901, and there is thus an excellent possibility that much ore of that grade remains in the lower stopes.

If the early company map correctly shows the approximate extent of mined and prospected areas, considerable unprospected ground remains in spite of the fact that the mine is surrounded by other claims that limit the lateral extention of operations. However, it should not be overlooked that underground workings, especially shallow ones, probably exist and were never shown on the company map. For example, plate 1 shows several dumps south of the shaft, but the company map indicates no workings at all in this area.

On the basis of present knowledge of the Altoona mine, the following suggestions for future development and prospecting are made.

(1) Examine the stoped areas on the lower levels. The back fill and remaining ore in the old stopes may average about 10 pounds of mercury per ton. This material is easily mined and would maintain production while new areas are being developed.

(2) Explore the possibility of an intersection of veins No. 1 and No. 2 north of the main shaft. The early company map (pl. 70) indicates a convergence of the two in that direction.

(3) A brecciated zone (shown as gouge on pl. 70) on the Altoona level just west of the shaft should be investigated, although the extent and significance of the brecciation was not determined in the accessible workings.

(4) Explore vein No. 4, especially at depth. It is not known whether this vein is a fault similar to veins No. 1 and 2 or the sheared contact between serpentine and diorite. The early company map shows vein No. 4 only on the Castella level. A projection of vein No. 4 downward, from what is probably its surface outcrop (gossan), to its position on the Castella level indicates a steep dip to the northeast. The possible intersection of this vein with veins No. 2 and 3 should be explored. It is very possible that the ore body on the Virginia level, shown on plate 70, was controlled by such an intersection, especially in view of the sharp bend the ore deposit makes on that level.

(5) Explore vein No. 3 from the Trinity and Goldstein levels in order to determine its dip and to see if it is offset by vein No. 4.

(6) Explore the Virginia level ore body. The early company map indicates low-grade ore on the footwall. Such ore probably averages about 10 pounds of mercury per ton.

(7) Since a depth of 600 feet is unusually great for quicksilver deposits, plans for prospecting to a greater depth should be made only with great caution.

HEALTH AND SAFETY WORK OF THE BUREAU OF MINES

By James Boyd, Director *

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INTRODUCTION

The Health and Safety Division of the Bureau of Mines comprises four branches: Safety, Coal Mine Inspection, Health, and Accident Analysis. These branches, functioning in related fields, are coordinated by the office of the Chief of the Division in Washington, D. C.

Laboratories and training headquarters are in the Bureau's building in Pittsburgh, Pennsylvania. Field activities, which are the major function of the Division, are carried on from field offices in centers of mining or mineral activity throughout the United States and Alaska.

The Safety Branch, employing engineers, safety instructors, and technicians, has as its activities:

First aid and mine rescue training.
Accident-prevention training; metal, nonmetal, metallurgical, and petroleum laboratories.
Routine dust and ventilation surveys at metal mines.
Conferences with mine and plant officials on safety problems.
Promotion of safety organizations and addressing safety meetings.
Exhibits, demonstrations, safety motion pictures.
Testing electrical and other equipment for permissibility.
Investigations of accidents and practices in the mineral industries.
Anthracite flood investigations.
Preparation of reports for publication.

The Coal Mine Inspection Branch, employing mine inspectors, engineers, and technicians, has as its chief activities:

Inspection of coal mines.
Routine dust and ventilation surveys at coal mines.

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* U. S. Department of the Interior, Bureau of Mines.

- Accident-prevention training, coal mining.
- Investigation of coal-mine disasters and other accidents.
- Attendance and talks at safety meetings.
- Conferences with mine officials and miners' safety committees relating to mine safety conditions.
- Mine fire control and prevention.
- Engineering studies of coal-mine methods and practices.
- Rescue and recovery operations.
- Preparation of reports for publication.

The Health Branch, employing chemists, engineers, and technicians, has as its activities:

- Health and sanitation studies in mines and mining communities.
- Research on physiological effects of gases and dusts.
- Detailed dust studies at mines and plants.
- Analysis of air samples for Coal Mine Inspection and Safety Branches.
- Testing and development of respiratory protective methods and devices.
- Studies of mine ventilation.
- Preparation of reports for publication.

The laboratory and testing work of the Health Branch is centralized at the Bureau laboratories at Pittsburgh, Pennsylvania.

The Accident Analysis Branch, employing mining engineers, statisticians, and clerks, has as its chief activities:

- Collection, checking, compilation, and publishing of official injury statistics on all mineral and allied industries. This includes not only mining and quarrying but also cement mills, lime plants, primary smelters of nonferrous metals, ore-dressing mills, and coke plants.
- Conducting five annual safety competitions.
- Collection, checking, compilation, and publication of consumption and other data on industrial explosives.

From the earliest period of the existence of the Bureau of Mines one of the main objectives of the Bureau's work was the prevention of loss of life and limb and the protection of the health of those who make available the mineral products vital to the life and progress of this country.

During the years that have intervened since the Bureau of Mines came into existence in 1910, it has consistently and continuously conducted an educational campaign aimed toward fulfillment of the objectives mentioned; educational procedures were used partly because the Bureau of Mines has no legal authority to enforce any suggestions or recommendations as to health, safety, or efficiency, and partly because it is believed that if those engaged in the work are kept informed as to what can or should be done they will eventually place those measures in effect.

The Safety Branch has long specialized in the instruction of workers in the mineral industries in first aid, mine rescue work, and accident prevention. Investigative and educational work is conducted in various fields of the industry jointly with engineers and inspectors of the other branches.

Functions and services of the Bureau regarding health hazards from gases and dusts and on ventilation from the aspects of health and safety are discussed in detail in the reviews that follow. They relate the history and work of the Bureau in those respects and present the services available to the mineral industry.

HEALTH WORK OF THE BUREAU OF MINES IN CONNECTION WITH DUST AND VENTILATION PROBLEMS

The duties of the Health Branch, in accordance with the organic act of July 1, 1910, creating the Bureau of Mines, are the investigation of health hazards and the development of measures for improving health conditions in the mineral industries in connection with the mining, preparation, and utilization of mineral substances and the dissemination of information concerning these investigations in such manner as will best carry out the purpose of the act. The Coal Mine Inspections and Investigations Act of May 7, 1941, increased the Health Branch's possibilities of promoting health in the coal mining industry by authorizing and empowering the Bureau to make annual or necessary inspections and investigations in coal mines relating to health conditions and the causes of occupational diseases.

A few of the health investigations conducted by the Branch include (1) general investigations, (2) the properties and toxicity of gaseous atmospheric contaminants, (3) the properties and physiologic action of particulate atmospheric contaminants (dusts), (4) physical condition of the atmosphere of working places (abnormal temperatures and humidities), (5) activities resulting from federal coal-mine inspections, (6) approval testing of commercial respiratory protective devices.

General Investigations

The investigations of the Health Branch deal principally with the hygienic aspects of abnormal environmental conditions to which workers in the mineral industries are exposed. Consideration is given especially to atmospheric health hazards. Studies include the measurement of various forms of atmospheric pollution; evaluation of the significance of such measurements; and development of methods of controlling the hazards incident to exposure thereto. These methods include detection of toxic gases and dusts and determination of the extent of their occurrence.

Results of the investigations are used in forming standards of allowable concentrations of atmospheric contaminants and other abnormal environmental conditions recommended by such organizations as the American Standards Association, the American Society of Heating and Ventilating Engineers, the Industrial Hygiene Foundation, the American Public Health Association, the Governmental Industrial Hygienists, and several similar organizations. Members of the Health Branch are serving in various capacities with many of these organizations.

Special Investigations

The first investigation of silicosis in the mining industry in the United States was made in 1914-15 by the Federal Bureau of Mines in cooperation with the United States Public Health Service in the Joplin (Missouri) mining district. Of 93 men examined, 64 showed plain and definite evidence of pulmonary disease, 3 were suffering from nonpulmonary disease, and 26 were seemingly well. To gain a more accurate idea of the prevalence of consumption among the miners of the Joplin district, it was decided to examine a large number, and from May 15 to December 31, 1915, 720 miners were examined; 45.7 percent had silicosis and tuberculosis and 5.3 percent had tuberculosis. A later report (1927) of this same investigation by Lanza and Childs included the results of the first detailed X-ray studies of silicosis made in the United States.

Investigations of mining conditions by Harrington and Lanza in Butte, Montana, in 1921, revealed that 42.4 percent of 1,018 miners examined showed definite signs of lung damage due to dust.

In 1923 the mining companies of the Tri-State district (comprising the zinc and lead-mining areas of southwestern Missouri, southeastern Kansas, and northeastern Oklahoma) requested the Federal Bureau of Mines to determine whether measures in use were adequate for the prevention of silicosis, and, if not, to recommend improvements. The 1923 investigation included the examination of 209 miners, 101 of whom were found to be negative, 114 doubtful, and 94 positive cases of silicosis. Of the positive group, 52 were in the first stage, 22 in the second stage, and 20 in the third stage of silicoiss.

From July 1, 1927 to June 30, 1932, the Metropolitan Life Insurance Co., the Tri-State Zinc & Lead Ore Producers Association, and the Federal Bureau of Mines operated a cooperative clinic at Picher, Oklahoma, to demonstrate to industry a workable method for diagnosing silicosis, to educate workers in preventive measures, and to serve as a model to industries presenting a dust hazard. Of 27,553 individuals examined during this period 5,366 had silicosis, 742 silicosis plus tuberculosis, and 320 uncomplicated tuberculosis. The 5-year study showed that, by careful physical examination and the application of proper dust-control measures, the incidence of silicosis and other dust diseases could be greatly reduced.

The following publications discuss the investigations mentioned above:

Lanza, A. J., and Higgins, Edwin, Pulmonary disease among miners of the Joplin District, Missouri, and its relation to rock dust in the mines: U. S. Bur. Mines Tech. Paper 105, 47 pp., 1915.

Higgins, E., Lanza, A. J., Laney, F. B., and Rice, G. S., Siliceous dust in relation to pulmonary disease among miners in the Joplin District, Missouri: U. S. Bur. Mines Bull. 132, 116 pp., 1917.

Lanza, A. J., and Childs, Samuel B., I. Miners' consumption—a study of the disease among zinc miners in southwestern Missouri; II. Roentgen-ray findings in miners' consumption: U. S. Public Health Bull. 85, 40 pp., 1917.

Harrington, Daniel, and Lanza, A. J., Miners' consumption in the mines of Butte, Montana: U. S. Bur. Mines Tech. Paper 260, 19 pp., 1921.

Sayers, R. R., Meriwether, F. V., Lanza, A. J., and Adams, W. W., Silicosis and tuberculosis among miners of the tri-state district of Oklahoma, Kansas, and Missouri, I. For year ended June 30, 1928; U. S. Bur. Mines Tech. Paper 545, 30 pp., 1933.

Meriwether, F. V., Sayers, R. R., and Lanza, A. J., Silicosis and tuberculosis among miners of the tri-state district of Oklahoma, Kansas, and Missouri, II. For the year ended June 30, 1929: U. S. Bur. Mines Tech. Paper 552, pp. 7-19, 1933.

SERVICES AND PUBLICATIONS AVAILABLE

The Health Branch has developed satisfactory methods for sampling and counting dust particles and for determining and analyzing them. At present various methods of analyzing dust are being studied. Some of these are by X-ray diffraction and petrographic, spectrochemical, and electrochemical procedures. However, the methods and instruments for determining air-dustiness developed by the Health Branch are used generally in the United States and make possible comparison of studies made in various industries.

Although no recent formal studies have been made on siliceous dust in relation to pulmonary diseases among miners, investigations and dust surveys are conducted regularly as requested by the mineral industry.

Many of the progressive mining companies have instituted and maintain excellent dust-control measures as a result of a series of dust studies conducted at their properties by Bureau of Mines engineers over a period of years. The mining engineers of the Bureau of Mines are available to the mining industry for such service at all times.

Numerous publications have been issued or are in preparation on various phases of the dust problem. These contain enough information, if properly applied, to greatly reduce or to eliminate the dust hazard in the mining industry. Some of these publications are listed below:

Littlefield, J. B., Feicht, F. L., and Schrenk, H. H., Bureau of Mines midget impinger for dust sampling: U. S. Bur. Mines Rept. Inv. 3360, 4 pp., 3 figs., 1937. Describes small, portable, hand-operated impinger; results obtained with silica dust agreed well with those obtained with regular impinger.

Schrenk, H. H., and Feicht, F. L., Bureau of Mines midget impinger: U. S. Bur. Mines Inf. Circ. 7076, 7 pp., 4 figs., 1939. Describes the midget impinger flash and suction apparatus developed by the Bureau, as well as the collecting and counting of dust samples; gives the results of laboratory tests with silica dust, lead dust, and lead fume and field tests on Catoctin greenstone and siliceous schist.

Brown, C. E., and Schrenk, H. H., A technique for use of the impinger method: U. S. Bur. Mines Inf. Circ. 7026, 20 pp., 4 figs., 1938. Describes procedure followed by Bureau of Mines in determining, by impinger method, number concentration of dust in atmospheres known to contain or suspected of containing pneumoconiosis-producing particulate matter.

Brown, C. E., Baum, L. A. H., Yant, W. P., and Schrenk, H. H., Microprojection method for counting impinger dust samples: U. S. Bur. Mines Rept. Inv. 3373, 9 pp., 4 figs., 1938. Supplements U. S. Bur. Mines Rept. Inv. 3289, which described new method for counting dust particles with microprojector, eliminating eyestrain. This applies same method to counting of impinger dust samples.

Brown, C. E., Midget microprojector for dust determinations: U. S. Bur. Mines Rept. Inv. 3780, 14 pp., 2 figs., 1944. Describes construction and application of small microprojector that is easy to use in making determinations of dust in atmosphere.

Brown, C. E., Filter-paper method for obtaining dust-concentration results comparable to impinger results: U. S. Bur. Mines Rept. Inv. 3788, 20 pp., 9 figs., 1945. A new filter-paper method for obtaining samples of air for dust analysis in health surveys is described. The device recovers dust from the air by drawing the atmosphere through a filter paper, instead of through liquid as in the "impinger" method long used for obtaining samples for scientific study.

Brown, C. E., and Yant, W. P., The microprojector for determining particle-size distribution and number concentration of atmospheric dust: U. S. Bur. Mines Rept. Inv. 3289, 8 pp., 3 figs., 1935. Describes apparatus and methods for examining samples of atmospheric dust by projecting images of the dust particles at a high known magnification onto a ruled translucent screen. Determination can be made with less eye strain, time, and effort than by direct visual microscopic methods.

Ballard, J. W., Oshry, H. I., and Schrenk, H. H., Some photometric instruments used in X-ray diffraction and spectrographic methods of analysis: U. S. Bur. Mines Rept. Inv. 3638, 13 pp., 9 figs., 1942. Describes such instruments in detail and discusses their application in the laboratory.

Brown, C. E., Beatty, R. L., and Kirby, T. B., Dust-counting cells: U. S. Bur. Mines Inf. Circ. 7331, 9 pp., 2 figs., 1945. This report contains information about dust-counting cells for scientists engaged in industrial studies of dust and its effect on health. Several types of counting cells, including a new dual cell, as well as methods of making simple and inexpensive ones are described in this paper.

APPROVAL TESTING OF RESPIRATORY PROTECTIVE DEVICES

To promote the development of safe, satisfactory, and reliable respiratory protective devices, the Bureau has established schedules of minimum requirements for self-contained oxygen-breathing apparatus, gas masks, supplied-air respirators (hose masks, airline respirators, and abrasive blasting helmets, hoods, or masks), mechanical filter respirators, and chemical cartridge respirators. With the exception of the self-contained oxygen-breathing apparatus, the Health Branch tests for approval all the types of apparatus mentioned. These devices are essential for protection against numerous gaseous and particulate contaminants present in the atmosphere of many industries.

Manufacturers of respiratory protective devices may submit their equipment to the Bureau for approval under the requirements of the schedules. Lists of approved devices are published periodically for the information of the public. About 158 devices of various types are on the latest list.

Some of the States and some municipalities require that apparatus used in their jurisdictions must be approved by the Federal Bureau of Mines.

HISTORY OF THE WORK OF THE BUREAU OF MINES ON MINE AND TUNNEL VENTILATION

The subject of mine and tunnel ventilation has two broad aspects; the health and safety aspect, that is, what atmospheric conditions to obtain in underground openings; and the engineering aspect, that is, how to maintain the desired conditions and particularly, how to do so efficiently. The health and safety aspect relates more particularly to quantity and quality requirements of ventilating systems, whereas the engineering aspect relates more particularly to pressure requirements. Both, therefore, determine power requirements, which is the deciding factor of practical importance in any system of mine or tunnel ventilation.

Both divisions of the subject have received considerable attention from the Bureau of Mines since its organization in May 1910, in the form of research, service, and correlation and dissemination of information. Numerous papers have been published on various phases of the subject, of which a selected list, numbered and arranged in chronological order by type of publication, will be found at the end of this paper. One of these, Technical Paper 705 (24),[1] gives a complete bibliography of Bureau of Mines publications dealing with health and safety. As is indicated by this selected list of publications, the health and safety aspect has received a major share of the attention devoted to this work, mostly because these have been dominant factors in Bureau policy but partly because this aspect lends itself to laboratory research and small-scale field studies. Although much attention has also been devoted to the engineering aspects of mine and tunnel ventilation, there has been only sporadic recognition of the vital effect this phase of the work could have on improving health and safety conditions.

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[1] Number refers to publications listed at end of paper.

1910-21

In the early work of the Bureau, a few specific field studies (1, 2) were made in which the emphasis was largely on safety, particularly as regards mine gases (3, 14, 25, 26, 28, 117). Serious dust studies were started in the Joplin, Missouri, district in 1914, where ventilaton was not considered to be a problem. When these studies were continued in 1916 in the Butte, Montana, mines, where ventilation was a serious problem, there was developed a particular and intense interest in the health and safety features of ventilation.

During the period 1916-21, Dan Harrington continued a study of underground air conditions in Butte mines (4, 15) and directed a limited corps of engineers and Public Health Service doctors engaged in field studies of dust—ventilation conditions in various western mining districts, on which many general (30, 41, 118, 119, 120, 121) and specific (31, 32, 33, 34, 36, 37, 38, 40, 42, 43, 51) publications were based.

Vehicular-Tunnel Ventilation Studies. Starting late in 1919 and continuing through 1921, an extensive investigation of the problems involved in ventilating vehicular tunnels was carried out in cooperation with the New York State and New Jersey Interstate Bridge and Tunnel Commissions and related to ventilation of the Holland tunnels which were being constructed under the Hudson River. This investigation was divided into four separate and distinct problems, which include (1) amount of the composition of exhaust gases from motor vehicles, conducted at the Pittsburgh Station, (2) physiological effect of exhaust gases from motor vehicles, conducted at Yale University, (3) determination of empirical factors for calculating the pressure requirements for flow of air through concrete ducts, conducted in cooperation with the Engineering Experiment Station of the University of Illinois at Urbana, Illinois, (4) determination of the relative merits of various methods of transverse ventilation for the Holland tunnels, conducted in a model tunnel constructed in the Bureau's Experimental mine, Bruceton, Pennsylvania.

Detailed results of parts 1, 2, and 4 have been published (13, 29, 35), but the results of part 3 are only briefly summarized in the yearly reports of the two commissions involved. The Bureau devoted a large amount of time and effort to these problems, which developed a continuing interest in toxic combustion gases (39, 58, 63, 113, 114, 128), including those in railroad tunnels (16, 46, 56, 60), and led to the development of a carbon-monoxide recorder (17) now widely used in vehicular tunnels and in industry.

1922-27

A comprehensive study on coal-mine ventilation factors was started in the Experimental mine late in 1921, requiring considerable development and testing of instruments and methods of procedure. Arrangements were made to do similar work in cooperation with the Anaconda Copper Mining Co. in its metal mines at Butte, Montana. The Experimental mine test work (6) was completed in 1923. The work at Butte was relatively more extensive and difficult, and continued, with a few interruptions, into 1927. Rather elaborate tests were made of fan-tubing installations (48, 49, 50), of the resistance of typical metal-mine airways (5, 132), of laboratory and field methods of testing fans (18, 137), of natural-draft ventilation (62), and of shaft air-temperature changes. Considerable attention was also devoted to a study of the application of air-conditioning to mines, then used only in one mine (52, 127) in Brazil, but no tests were made. Resistance tests on rough coal-mine airways were made in an Indiana coal mine and in the Moffat tunnel (135), Colorado, then under construction.

During the time the Butte work was in progress and largely resulting from underground observations (45, 109, 110) made previous to the tunnel-gas studies, a very extensive series of laboratory tests on the effect of air conditions on comfort was carried on at the Pittsburgh Station in cooperation with the American Society of Heating and Ventilating Engineers. The results, as reported in a series of Bureau of Mines (53, 55, 54), Public Health Service (111, 112), A. S. H. V. E. (122, 123, 124, 125, 126, 129), and other publications (140, 143, 144), resulted in the formulation of a new concept—effective temperature—for expressing the interrelation of air temperatures, humidity, and movement on sensations of comfort. Later, the Research Laboratory of the A. S. H. V. E. made numerous additional tests to amplify this subject and developed charts for practical application of this information which are published yearly in the A. S. H. V. E. ''Guide.''

During this same period extensive field studies were made of blasting gases (7, 59) in metal mines and tunnels and of the occurrence of rock-strata gases (8) in the mines of the Cripple Creek district, Colorado. Tests were also made in the Experimental mine at Bruceton on the recirculation of gas caused by auxiliary fans as used in coal mines, with results (136) that have guided mine inspection policies in this matter. A number of papers on particular activities (19, 44, 47, 61) or of general interest (57, 130, 131, 133, 134, 138, 139) to mine ventilation appeared also during this period.

1928-41

The Health Branch concerned itself mainly with laboratory studies, mostly of a pathological nature, on the effects of gases, toxic vapors, and dust. Few field studies were made, although interest in the physiological factors of mine ventilation (72, 76, 77, 80, 85, 100, 102, 142, 146) continued.

One large study made in 1941 stemmed directly from the previous tunnel-gas investigations made in connection with the Holland tunnels. At the request of the New York City Tunnel Authority, the Bureau conducted a series of wind-tunnel model tests to determine the rate of dilution of gases discharged from stacks (22), as a result of which the proposed design of the ventilation arrangements for the Manhattan end of the Battery-Brooklyn vehicular tunnel was radically altered.

During this period, incidental attention to ventilation (10, 11, 21, 64, 73, 74, 75, 78, 81, 82, 84, 87, 88, 89, 91, 92, 93, 94, 95, 96, 97, 98, 99, 101, 115, 116, 141, 146) produced a large number of short papers of both general and particular interest as regards the relation of ventilation and mine safety.

Studies of ventilation methods were made in a number of mining districts (9, 20, 79, 90) and individual mines, the available information on several phases was correlated (65, 71, 83, 86), and a general bulletin on mine ventilation (12) was prepared, which is used not only as a textbook in many university mining courses, but also appears, in a condensed form, as the section (145) on mine ventilation in the mining engineers' ''bible''—Peele's Mining Engineers Handbook. A special study was made of the conditions of jet flow at the discharge of fan-pipe lines in the Bureau's Mount Weather adit, Bluemont, Virginia; the results (66, 67) have been correlated with results of other jet research in a way that has served as a pattern for analyzing the results of later research in industrial ventilation.

1942-49

Immediately before and during the war the Bureau was engaged on many special war problems, several of which utilized the Bureau's experience in mine ventilation. The most interesting and important problem (108), and one that fully utilized the Bureau's experience in ventilation and toxic gases, was a study, carried out in cooperation with the Bureau of Ships of the Navy, of the ventilation of tank landing (LST) ships as required to combat the hazard of carbon monoxide poisoning of crew members during prolonged warming-up of tank and vehicle engines in closed holds.

In recent years, both the Health Branch and the Safety Branch have maintained an interest in ventilation problems, although mostly along educational lines (23, 27, 104, 105, 106, 147, 148). Special studies have been made on the use of Diesel engines underground (68, 69, 103, 107); engineering studies have been made in coal mines, particularly on the application of pressure-surveying methods, on the ''stall'' troubles introduced by axial-flow fans, and on the application of fan-tubing auxiliary ventilation; occasional surveys have been made in both coal and metal mines and developments in both have been closely followed; developments in the application of air-conditioning to mines have been followed continuously since 1936, for which purpose a special psychrometric chart (70) was recently perfected after a number of unsatisfactory attempts dating back to the early work at Butte in the twenties.

LIST OF BUREAU OF MINES PUBLICATIONS DEALING WITH THE VENTILATION OF MINES AND TUNNELS

Bulletins

(1) Williams, R. Y., The humidity of mine air, with especial reference to coal mines in Illinois: U. S. Bur. Mines Bull. 83, 69 pp., 2 pls., 7 figs., 1914.

(2) Williams, R. Y., Mine ventilation stoppings, with especial reference to coal mines in Illinois: U. S. Bur. Mines Bull. 99, 33 pp., 4 pls., 4 figs., 1915.

(3) Burrell, G. A., Robertson, I. W., and Oberfell, G. G., Black damp in mines: U. S. Bur. Mines Bull. 105, 88 pp., 1916.

(4) Harrington, D., Underground ventilation at Butte: U. S. Bur. Mines Bull. 204, 131 pp., 3 pls., 42 figs., 1923.

(5) McElroy, G. E., and Richardson, A. S., Resistance of metal-mine airways: U. S. Bur. Mines Bull. 261, 145 pp., 71 figs., 1927.

(6) Greenwald, H. P., and McElroy, G. E., Coal-mine ventilation factors: U. S. Bur. Mines Bull. 285, 106 pp., 47 figs., 1929.

(7) Gardner, E. D., Howell, S. P., and Jones, G. W., Gases from blasting in tunnels and metal-mine drifts: U. S. Bur. Mines Bull. 287, 96 pp., 14 figs., 1927.

(8) Denny, E. H., Marshall, K. L., Fieldner, A. C., Emery, A. H., Yant, W. P., and Selvig, W. A., Rock-strata gases of the Cripple Creek district, Colorado, and their effect on mining: U. S. Bur. Mines Bull. 317, 66 pp., 21 figs., 1930.

(9) McElroy, G. E., Ventilation of the large copper mines of Arizona: U. S. Bur. Mines Bull. 330, 145 pp., 42 figs., 1931.
(10) Harrington, D., and Denny, E. H., Gases that occur in metal mines: U. S. Bur. Mines Bull. 347, 21 pp., 1931.
(11) Ash, S. H., and Rankin, J. H., Permissible electric cap lamps and ventilation in certain California mines and water-tunnel construction: U. S. Bur. Mines Bull. 359, 36 pp., 12 figs., 1932.
(12) McElroy, G. E., Engineering factors in the ventilation of metal mines: U. S. Bur. Mines Bull. 385, 196 pp., 68 figs., 1935.

Monograph

(13) Fieldner, A. C., Henderson, Yandell, Paul, J. W., Sayers, R. R., and others, Ventilation of vehicular tunnels: U. S. Bur. Mines Mon. 1, 171 pp., 69 figs., 1927.

Technical Papers

(14) Burrell, G. A., and Seibert, F. M., The inflammable gases in mine air: U. S. Bur. Mines Tech. Paper 39, 24 pp., 2 figs., 1913.
(15) Harrington, D., Ventilation in metal mines, a preliminary report: U. S. Bur. Mines Tech. Paper 251, 44 pp., 1921.
(16) Fieldner, A. C., Katz, S. H., and Kinney, S. P., Tests of gas masks and respirators for protection from locomotive smoke in railroad tunnels, with analyses of tunnel atmospheres: U. S. Bur. Mines Tech. Paper 292, 27 pp., 3 pls., 3 figs., 1922.
(17) Katz, S. H., Reynolds, D. A., Frevert, H. W., and Bloomfield, J. J., A carbon monoxide recorder and alarm: U. S. Bur. Mines Tech. Paper 355, 35 pp., 3 pls., 13 figs., 1926.
(18) McElroy, G. E., and Richardson, A. S., Experiments on mine fan performance: U. S. Bur. Mines Tech. Paper 447, 61 pp., 32 figs., 1929.
(19) Ash, S. H., Explosions in Washington coal mines: U. S. Bur. Mines Tech. Paper 507, 52 pp., 1931.
(20) McElroy, G. E., Natural ventilation of Michigan copper mines: U. S. Bur. Mines Tech. Paper 516, 40 pp., 5 figs., 1932.
(21) Ash, S. H., Safety factors in construction and ventilation, Wawona vehicular tunnel, Yosemite National Park, California: U. S. Bur. Mines Tech. Paper 608, 34 pp., 21 figs., 1940.
(22) McElroy, G. E., Brown, C. E., Berger, L. B., and Schrenk, H. H., Dilution of stack effluents: U. S. Bur. Mines Tech. Paper 657, 46 pp., 33 figs., 1944.
(23) McElroy, G. E., Design of injectors for low-pressure air flow: U. S. Bur. Mines Tech. Paper 678, 50 pp., 13 figs., 1945. (Abstracted in Heating and Ventilation, pp. 82-94, July 1947.)
(24) Davenport, Sara J., Bibliography of Bureau of Mines publications dealing with health and safety in the mineral and allied industries, 1910-46: U. S. Bur. Mines Tech. Paper 705, 154 pp., 1948.

Miners' Circulars

(25) Burrell, G. A., and Seibert, F. M., Gases found in coal mines: U. S. Bur. Mines Miners' Circ. 14, 23 pp., 1914.
(26) Rutledge, J. J., Hints on coal-mining ventilation: U. S. Bur. Mines Miners' Circ. 16, 22 pp., 1914.
(27) Fires, gases and ventilation in metal mines: U. S. Bur. Mines Miners' Circ., Metal Mine Accident Prevention Course, Sections 5, 94 pp., 42 figs., 1946.

Chart

(28) Burrell, G. A., Chart of properties of mine gases: U. S. Bur. Mines Chart, 1918.

Reports of Investigations

(29) Fieldner, A. C., Automobile exhaust gases in vehicular tunnels: U. S. Bur. Mines Rept. Inv. 2103, 3 pp., 1920.
(30) Harrington, D., Metal-mine ventilation and its relation to safety and efficiency in mining operations: U. S. Bur. Mines Rept. Inv. 2133, 8 pp., 1920.

(31) Harrington, D., Compressed-air blowers in metal mines: U. S. Bur. Mines Rept. Inv. 2246, 5 pp., 1921.

(32) Gardner, E. D., Compressed-air-operated ventilation doors in Arizona copper mines: U. S. Bur. Mines Rept. Inv. 2273, 2 pp., 1 fig., 1921.

(33) McElroy, G. E., Rock-strata gases in mines of the East Tintic mining district, Utah: U. S. Bur. Mines Rept. Inv. 2275, 3 pp., 1921.

(34) McElroy, G. E., Hot high-nitrogen gas in a metal mine: U. S. Bur. Mines Rept. Inv. 2282, 3 pp., 1921.

(35) Fieldner, A. C., and Paul, J. W., Bureau of Mines experimental tunnel for studying the removal of automotive-exhaust gas: U. S. Bur. Mines Rept. Inv. 2288, 3 pp., 1921.

(36) Pickard, B. O., and Gardner, E. D., Methane in California gold mines: U. S. Bur. Mines Rept. Inv. 2303, 6 pp., 1921.

(37) Ageton, R. B., Compressed-air blowers as an aid to metal-mine-ventilation: U. S. Bur. Mines Rept. Inv. 2309, 5 pp., 1922.

(38) Harrington, D., and McElroy, G. E., Performance of fan-pipe installation in metal mines: U. S. Bur. Mines Rept. Inv. 2320, 4 pp., 1922.

(39) Sayers, R. R., Meriwether, F. V., and Yant, W. P., Physiological effects of exposure to low concentrations of carbon monoxide: U. S. Bur. Mines Rept. Inv. 2338, 6 pp., 1922.

(40) Harrington, D., and McElroy, G. E., Determination of the relative comfort of mine working places by means of the datathermometer: U. S. Bur. Mines Rept. Inv. 2355, 7 pp., 1922.

(41) Harrington, D., Summary of investigations of dust and ventilation in metal mines: U. S. Bur. Mines Rept. Inv. 2374, 6 pp., 1922.

(42) Harrington, D., Fire and ventilation doors in metal mines: U. S. Bur. Mines Rept. Inv. 2426, 5 pp., 1 fig., 1922.

(43) Gardner, E. D., Rock-strata gases in mines of a Nevada mining district: U. S. Bur. Mines Rept. Inv. 2427, 4 pp., 1922.

(44) Rice, G. S., Paul, J. W., and Denny, E. H., Preliminary investigation of brattice cloth used in coal mining: U. S. Bur. Mines Rept. Inv. 2448, 4 pp., 1923.

(45) Sayers, R. R., and Harrington, D., Physiological effect of high temperatures and humidities with and without air movement: U. S. Bur. Mines Rept. Inv. 2464, 7 pp., 1 fig., 1923.

(46) Kinney, S. P., Atmospheric conditions and physiological effects produced on trainmen by locomotive smoke in the Aspen and Wasatch tunnels of the Union Pacific Railroad: U. S. Bur. Mines Rept. Inv. 2494, 13 pp., 1 fig., 1923.

(47) Katz, S. H., and Bloomfield, J. J., Sulphur trioxide smoke tubes for determining air currents: U. S. Bur. Mines Rept. Inv. 2505, 1 p., 1 fig., 1923.

(48) McElroy, G. E., and Richardson, A. S., Experiments on fan-pipe installations at Butte, Montana: U. S. Bur. Mines Rept. Inv. 2509, 14 pp., 1923.

(49) McElroy, G. E., and Richardson, A. S., Air-measurement methods for experimental work on fan-pipe installations: U. S. Bur. Mines Rept. Inv. 2527, 18 pp., 10 figs., 1923.

(50) McElroy, G. E., and Richardson, A. S., Friction factors for fan piping used in mine ventilation: U. S. Bur. Mines Rept. Inv. 2540, 15 pp., 5 figs., 1923.

(51) Harrington, D., Distribution of air in metal-mine ventilation, with especial reference to flexible-tubing methods: U. S. Bur. Mines Rept. Inv. 2551, 11 pp., 1923.

(52) Read, T. T., and Houghten, F. C., Cooling of mine air: U. S. Bur. Mines Rept. Inv. 2554, 19 pp., 1923.

(53) Houghten, F. C., Yaglaglou, C. P., and Sayers, R. R., Effective temperatures for still-air conditions and their application to mining: U. S. Bur. Mines Rept. Inv. 2563, 10 pp., 8 figs., 1924.

(54) McConnell, W. J., and Yaglaglou, C. P., The katathermometer—its value and defects: U. S. Bur. Mines Rept. Inv. 2565, 12 pp., 3 figs., 1924.

(55) McConnell, W. J., and Sayers, R. R., Some effects on man of high temperatures: U. S. Bur. Mines Rept. Inv. 2584, 13 pp., 8 figs., 1924.

(56) Katz, S. H., and Meiter, E. G., Temperatures in cabs of freight locomotives passing through tunnels of the Chesapeake and Ohio Railway: U. S. Bur. Mines Rept. Inv. 2624, 8 pp., 6 figs., 1924.

(57) Harrington, D., and von Bernewitz, M. V., Some features of ventilating fans at 164 coal and metal mines: U. S. Bur. Mines Rept. Inv. 2637, 5 pp., 1924.

(58) Sayers, R. R., Fieldner, A. C., Yant, W. P., Thomas, B. G. H., and McConnell, W. J., Exhaust gases from engines using ethyl gasoline: U. S. Bur. Mines Rept. Inv. 2661, 24 pp., 3 figs., 1924.
(59) Gardner, E. D., Jones, G. W., and Sullivan, J. D., Gases from blasting in heavy sulphides: U. S. Bur. Mines Rept. Inv. 2739, 8 pp., 1926.
(60) Sayers, R. R., Berger, L. B., and Yant, W. P., Tests of atmospheres in Chesapeake and Ohio Railway tunnels between Clifton Forge, Virginia, and Hinton, West Virginia: U. S. Bur. Mines Rept. Inv. 2858, 19 pp., 1 fig., 1928.
(61) Rice, G. S., and Owings, C. W., The use of brattice cloth in coal mines: U. S. Bur. Mines Rept. Inv. 2872, 8 pp., 1928.
(62) McElroy, G. E., and Richardson, A. S., Determining the air-flow resistance of a small shaft mine by natural draft: U. S. Bur. Mines Rept. Inv. 2890, 15 pp., 2 figs., 1928.
(63) Yant, W. P., and Berger, L. B., Carbon monoxide from automobiles using ethyl gasoline: U. S. Bur. Mines Rept. Inv. 2908, 8 pp., 1929.
(64) Owings, C. W., A novel method of ventilating a Pennsylvania coal mine: U. S. Bur. Mines Rept. Inv. 3127, 8 pp., 1931.
(65) McElroy, G. E., Charts for determining the performance of centrifugal fans: U. S. Bur. Mines Rept. Inv. 3298, 30 pp., 35 figs., 1936.
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MINES AND MINERAL RESOURCES OF YOLO COUNTY

By J. C. O'Brien *

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ABSTRACT

Yolo County is one of the original 27 counties of California. It is situated in the southwestern part of the fertile Sacramento Valley and 85 percent of its 661,770 acres is in farm land. Its principal mineral production has come from the quicksilver mines in the northwestern corner of the county. These properties were idle when the field work was done for this report early in 1949. The principal activity at that time was in the production of sand and gravel from Cache Creek and Putah Creek. There are 444 acres of proven gas lands in the county with two wells on production and four standing shut-in. The record of the production of other minerals is included from earlier reports.

INTRODUCTION

Yolo County is one of the 27 California counties that were created February 28, 1850. Its name was derived from a corruption of Yoloy, the name of an Indian tribe which inhabited the county when it was first settled. The county occupies one of the most fertile portions of the Sacramento Valley. Farming is by far the leading industry and sugar beets are the principal crop. The county has a population of 34,000, an increase of 25 percent since the 1940 census. Woodland, the county seat and largest city, had a population of 8,500 in 1944. It is also the major industrial center with a sugar refinery, fruit and vegetable packing plants, and stock yards.

The climate is dry and generally rainless from May to October but an average of 17 inches of rain falls during the winter months. Snow rarely falls but killing frosts are expected between November 15th and March 20th. The normal mean temperature for January and February is 48 degrees. The average July temperature is 77 degrees. The crop growing season averages 268 days.

Geography. Yolo County is situated in the southwestern part of the Sacramento Valley. It is bordered on the north by Colusa, on the east by

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* District Mining Engineer, California State Division of Mines.

Sutter and Sacramento, on the south by Solano, and on the west by Napa and Lake Counties. It includes 661,770 acres, of which 86 percent or 569,139 acres are privately owned; and 92,621 acres are public lands. There are 481,877 acres in farms and 87,262 acres in forest or grazing lands. Bounded on the east by the Sacramento River, most of the county is in the broad, level floor of the Yolo Basin. The land rises gradually westward into the low foothills of the Coast Range mountains which form the western border of the Sacramento Valley. Elevations are lowest from one to six miles west of the Sacramento River and highest along the western boundary, where a maximum elevation of 1,500 feet is reached. Drainage is northeastward toward the Sacramento River. The principal water resources are Cache and Putah Creeks and Willow Slough. Cache Creek flows from Clear Lake in Lake County and enters Yolo County at the northwestern corner. It flows southeastward and then eastward across the center of the county. Putah Creek rises in the mountains of Napa County and flows eastward forming the southern boundary of the county west of Davis. Both Cache and Putah Creeks are important streams during the rainy season but in the summer months their water disappears before entering the Yolo Bypass. They have cut their way through canyons in the mountains and deposited beds of sand and gravel in the broad valley.

Transportation. The main line of the Southern Pacific Railroad runs northward through Davis and Woodland. There are branch lines to Marysville, Winters, and Madison, and to Sacramento, which is on the main line to the east. The Sacramento Northern Railway and its branches operate freight trains in the eastern portion of the county. U. S. Highway 99 W is the main thoroughfare in the east central part of the county; State Highway 16 follows Cache Creek in the west connecting that area with Woodland and Sacramento; and State Highway 28 follows the southern boundary of the county connecting Winters, Davis, and Sacramento. In addition, a total of 875 miles of county and 112 miles of privately maintained roads complete the highway system.

Geology. The geology of Yolo County [1] is shown on the Geologic Map of California.

The eastern half of the county lying in the Sacramento Valley is covered with alluvium deposited by the Sacramento River and Cache and Putah Creeks in their flood periods. It includes some of the most fertile land in California. A belt of Pliocene non-marine sediments about 10 miles wide trends northwestward through the north-central portion of the county and a strip about four miles wide extends south along the Coast Range foothills to the southern border. Quaternary and Upper Pliocene sediments lie along the borders of the Pliocene non-marine sediments and the Quaternary alluvium. A narrow strip of upper Eocene marine sediments is exposed on the west side of Cache Creek for about 12 miles below Rumsey. The Coast Range, which forms the western border of the county, is covered with Upper and Lower Cretaceous marine sediments. In the extreme northwest corner of Yolo County, a small area of Tertiary volcanic rocks lies between Jurassic serpentine on the west and the Knoxville formation, which outcrops over an area of 25 square miles. Deposits of quicksilver have been mined in this small area and it is the only metal that has been produced in the county except for a small amount of gold and silver recovered from placers along Cache and Putah Creeks.

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[1] Jenkins, O. P., Geologic map of California, scale 1:500,000: California Div. Mines, 1938.

MINERAL RESOURCES

The principal resources of Yolo County are agricultural, and the value of farm products amounted to $42,957,714 in 1947. The total mineral production from 1873 to 1947 amounts to only $4,183,828. Quicksilver, produced from the mines in the northwestern corner of the county, was the chief mineral product, followed by miscellaneous stone, sandstone, and natural gas. A few thousand dollars in gold were mined from Cache and Putah Creeks. Some low grade gold quartz veins were found in the western foothills but no gold mines have been developed. Common brick was reported manufactured from clay beds near Woodland, Winters, and Capay,[2] but the industry has been idle for many years. Quicksilver mines are able to operate only in abnormal periods when the price of quicksilver is high. The mines were idle when the field work was done for this report. The principal activity was in the sand and gravel business, and practically all of this material was being used to build roads and driveways. Natural gas from two wells in the Fairfield Knolls gas field flows into the Rio Vista gas line, and there are four potential producing gas wells standing shut-in in the Dunnigan Hills area north of Woodland. There were 444 acres included in the proven gas fields in December, 1947.[3]

The mineral production of Yolo County, 1873-1947, is listed in table 1.

Building Stone[4]

Bluish-gray sandstone was quarried at the Devil's Gate, in Putah Canyon, about 9 miles west of Winters between 1894 and 1908. The stone occurs in beds from 12 to 15 feet thick, and it has frequently been split into slabs 14 feet long, 16 inches wide, and 10 inches thick. It has a smooth grain free from pebbles and was used for monuments and as a building stone for many years.

A volcanic tuff deposit occurs in the foothills west of Winters. Selected material was used to build houses in Winters many years ago. It is a soft whitish rock which becomes hard on exposure to the air and appears to weather remarkably well.

Clay

The manufacture of common brick was a thriving industry in the early days in Yolo County.[5] There were three brickyards operating in the southeastern part of Woodland. The clay was taken from a bed five to ten feet thick lying above a layer of sand. Both hand- and machine-made bricks were manufactured. They were burned in open kilns using willow and cottonwood wood for fuel. Hand-made bricks were made at Winters from a clayey loam taken from a bed about 20 feet thick which occurs on the north bank of Putah Creek. This material was mixed with some sand to make the brick. Bricks were also made in a brickyard near Capay from a clayey loam, which contained sufficient sand to prevent cracking.

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[2] Watts, W. L., Yolo County: California Min. Bur. Rept. 10, pp. 791-792, 1890.
[3] California Oil Fields: California Div. Oil and Gas, vol. 33, no. 2, p. 82, 1947.
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[5] Watts, E. L., Yolo County: California Min. Bur. Rept. 10, p. 791, 1890.

Table 1. Mineral production of Yolo County, 1873-1947.

Year	Quicksilver		Sandstone		Miscellaneous stone,[1] value	Miscellaneous and unapportioned		
	Flasks	Value	Cubic feet	Value		Amount	Value	Substance
1873	[2]995	$79,928	--------	--------	--------	--------	--------	
1874	3,000	315,540	--------	--------	--------	--------	--------	
1875	--------	--------	--------	--------	--------	--------	--------	
1876	965	42,460	--------	--------	--------	--------	--------	
1877	1,516	56,547	--------	--------	--------	--------	--------	
1878	1,640	53,956	--------	--------	--------	--------	--------	
1879	1,110	33,134	--------	--------	--------	--------	--------	
1880	422	13,082	--------	--------	--------	--------	--------	
1881	--------	--------	--------	--------	--------	--------	--------	
1894	--------	--------	2,500	$1,000	--------	--------	--------	
1895	--------	--------	542	1,873	--------	--------	--------	
1896	--------	--------	252	378	--------	--------	--------	
1897	--------	--------	--------	--------	--------	--------	--------	
1898	--------	--------	264	384	--------	--------	--------	
1899	--------	--------	264	384	--------	--------	--------	
1900	--------	--------	908	1,760	--------	--------	--------	
1901	--------	--------	1,540	2,300	--------	--------	--------	
1902	--------	--------	328	450	--------	--------	--------	
1903	--------	--------	280	144	--------	--------	--------	
1904	--------	--------	180	720	--------	--------	--------	
1905	--------	--------	175	200	--------	--------	--------	
1906	--------	--------	160	204	--------	--------	--------	
1907	--------	--------	250	350	--------	--------	--------	
1908	--------	--------	140	1,150	--------	--------	--------	
1909	--------	--------	--------	--------	--------	--------	--------	
1910	--------	--------	--------	--------	--------	--------	--------	
1911	--------	--------	--------	--------	--------	--------	--------	
1912	--------	--------	--------	--------	--------	--------	--------	
1913	--------	--------	--------	--------	--------	--------	--------	
1914	15	736	--------	--------	--------	--------	--------	
1915	[3]	--------	--------	--------	$1,200	--------	$840	Other minerals.
1916	--------	--------	--------	--------	300	--------	--------	
1917	[3]	--------	--------	--------	4,300	--------	1,261	Other minerals.
1918	[3]	--------	--------	--------	17,915	--------	3,300	Other minerals.
1919	[3]	--------	--------	--------	5,600	--------	19,866	Other minerals.
1920	--------	--------	--------	--------	9,472	--------	--------	
1921	--------	--------	--------	--------	14,829	--------	--------	
1922	--------	--------	--------	--------	[3]	--------	13,431	Unapportioned.
1923	--------	--------	--------	--------	[3]	--------	16,957	Unapportioned.
1924	--------	--------	--------	--------	[3]	--------	15,800	Unapportioned.
1925	--------	--------	--------	--------	23,060	--------	--------	
1926	--------	--------	--------	--------	20,560	--------	--------	
1927	--------	--------	--------	--------	17,895	--------	--------	
1928	--------	--------	--------	--------	17,200	--------	--------	
1929	--------	--------	--------	--------	14,400	--------	--------	
1930	--------	--------	--------	--------	2,700	--------	--------	
1931	--------	--------	--------	--------	21,500	--------	--------	
1932	--------	--------	--------	--------	21,625	--------	--------	
1933	--------	--------	--------	--------	16,694	--------	129	Gold.
1934	--------	--------	--------	--------	37,850	1 fine oz.	1 176	Silver. Gold.
1935	--------	--------	--------	--------	33,950	--------	715	Gold.
1936	--------	--------	--------	--------	71,434	--------	175	Other minerals.
1937	--------	--------	--------	--------	40,765	-------- -------- --------	1,330 4 2,072	Gold. Silver. Other minerals.
1938	[3]	--------	--------	--------	44,598	--------	3,634	Natural gas, quicksilver.
1939	[3]	--------	--------	--------	61,057	--------	2,087	Natural gas, quicksilver.
1940	[3]	--------	--------	--------	24,208	--------	85,612	Natural gas, quicksilver.
1941	[3]	--------	--------	--------	130,085	--------	151,218	Natural gas, quicksilver.
1942	[3]	--------	--------	--------	150,066	--------	467,352	Natural gas, quicksilver.
1943	[3]	--------	--------	--------	38,653	--------	326,523	Natural gas, quicksilver.
1944	[3]	--------	--------	--------	52,724	--------	341,575	Natural gas, quicksilver.
1945	[3]	--------	--------	--------	118,309	--------	361,501	Natural gas, quicksilver.
1946	[3]	--------	--------	--------	203,936	--------	283,876	Natural gas, quicksilver.
1947	[3]	--------	--------	--------	70,276	--------	191,152	Natural gas, quicksilver.
Totals	[3]9,663	$595,383	7,783	$11,297	$1,287,161	--------	$2,290,587	

Grand total value $4,184,428.

[1] Includes crushed rock, sand, gravel.

[2] Flasks of 76½ pounds, previous to June, 1904; of 75 pounds thence, through 1927; of 76 pounds since January, 1928.

[3] See under "Unapportioned."

Gold

Small scale placer mining has been done along the foothills of the Coast Range, and a small mining camp was located near the mouth of Putah Creek in the early days. A few thousand dollars in gold was produced from Putah Creek from 1933 to 1937.

Limestone

No limestone production has been recorded from Yolo County.[6] Years ago, mention was made of a limestone deposit reported to be in secs. 30 and 31, T. 10 N., R. 2 W., M. D., 3 miles south of Cadenassa Station.[7] Pliocene non-marine sediments occur [8] along the east side of this valley. The higher land on both sides of the valley is occupied by older marine sedimentary rocks, principally Upper Cretaceous, and in these rocks it is not unusual to find occasional small bodies of hard limestone. This is probably the explanation of the lumps and boulders of such limestone found, which could not be traced to a deposit in place. The soft limestone may eventually have value for agricultural use.

Table 2. Analysis of samples of "float" limestone, Yolo County.

Float limestone	J. H. Cranston	Stephens A. & L. Co.
SiO_2	6.60%	1.40%
R_2O_3	0.60	0.50
CaO	50.23	54.25
MgO	0.70	-----
CO_2	40.90	42.65
H_2O and volatile	1.00	1.10
	100.15%	99.90%

Mineral Water

There are a number of mineral springs in the hills in the western part of Yolo County [9] but none of them have been commercialized.

A saline spring flows on the line between secs. 25 and 26, T. 12 N., R. 5 W., M. D., near the Reed mine. There is a soda spring in the same area, and a sulphur spring above Fiske Creek, west of Rumsey on the Reed mine road. A sulphur-iron-magnesia spring located on the Smith Ranch, 4 miles west of Guinda, is used domestically but two white sulphur springs on the same property are unused.

There are several sulphur springs on Putah Creek near Devil's Gate, west of Winters.

Miscellaneous Stone

The principal mining activity in Yolo County in 1948 was the production of sand and gravel from pits on Cache and Putah Creeks. These creeks carry a considerable amount of water where they first enter the county but the volume decreases as they flow eastward. Cache Creek flows southeastward from the northwestern corner of the county, turns eastward in the vicinity of Capay, and continues through the central portion of the county towards the Sacramento River. Its banks are gravel, covered with sandy, tan soil. They are about 5 feet high where the stream enters the valley near Capay, but rise from 10 to 20 feet in places between Esparto and Yolo. Shifting seasonable waters have deposited sand, gravel, and silt in layers and lenses on terraces and bars half a mile wide in many places along its course. The few boulders and cobbles seldom exceed 6 inches in size. The cobbles and coarse pebbles are mostly red, green, and brown jasper, often having many thin seams of white quartz. The greatest amount of the gravel consists of subangular and rounded pebbles of volcanic origin, mostly andesite. Serpentine pebbles were noted only in the gravel taken from creeks in the western portion of the county.

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[6] Logan, C. A., Limestone in California: California Div. Mines Rept. 43, p. 350, 1947.

[7] Bradley, W. W., Yolo County: California Min. Bur. Rept. 14, p. 368, 1913.

[8] Jenkins, O. P., Geologic map of California, scale 1:500,000, California Div. Mines, 1938.

[9] Bradley, W. W., Yolo County: California Min. Bur. Rept. 14, p. 369, 1913.

Putah Creek rises in the mountains of Napa County and flows eastward to form 24 miles of the southern boundary of Yolo County. Like Cache Creek, it flows a torrent in the rainy season but it is confined in a narrower channel with banks 20 to 30 feet high. There are few boulders, and the gravel consists of subangular pebbles of volcanic origin including white and gray andesite and rhyolite, red basalt, angular fragments of quartz, red and green jasper, and some serpentine. Gravel pits are located on terraces and bars in Putah Creek south of Winters where the channel is about a quarter of a mile wide.

The Cache Creek Sand and Gravel Company (Yolo Gravel Company) is owned and operated by Leroy Kerr, Box 34, Yolo, California. It is located on the north bank of Cache Creek in the W½ sec. 14, T. 10 N., R. 1 E., M. D., on land owned by Kerr; an adjoining quarter of a mile northeast along the creek is leased from Lois C. Campbell of San Francisco. The gravel lies in two broad benches from 5 to 10 feet above the creek. It is 2,500 feet wide on the south end and 300 feet wide on the end half a mile northeast. There are no boulders and few cobbles at this location. The gravel is dug about 6 feet deep where a layer of clay is encountered. Equipment includes a Bay City dragline fitted with a 30-foot boom and a ½-cubic-yard bucket; a P & H dragline with a 30-foot boom and a ⅝-cubic-yard bucket; a P & H shovel with a ¾-cubic-yard bucket; and seven dump trucks having 4-, 5-, 7-, and 8-cubic-yard capacities.

The washing and screening plant includes a 25-cubic-yard wooden hopper into which the trucks discharge the material dug from the pit. An apron feeder below the hopper feeds a belt conveyor 18 inches wide and 175 feet long, which is driven by a 10-horsepower motor. The conveyor discharges the material into a trommel 4 feet in diameter and 16 feet long having ¾- and 1½-inch holes. Material over 1½-inch in size drops into a 20-cubic-yard bin and is hauled to a stock pile. It is sold principally for filling drains. The minus 1½-inch material goes to a 3- by 6-foot double-deck vibrating screen driven by a 5-horsepower motor. Bins holding 20 cubic yards each are provided for — 1½ to + ¾-inch, — ¾ to + ⅜-inch material, and sand. All the material is washed as it passes through the trommel and on the screens. Wash water is pumped from a well 187 feet deep by a Layne and Bowler pump driven by a 20-horsepower motor. The water in Cache Creek sinks beneath the surface in this pit at a horizon about 8 feet below the surface of the surrounding gravel. The sand is dewatered in a spiral classifier. Trucks are loaded through gates in the bottom of the bins.

Stock piles of screened gravel are maintained at the plant. The gravel is used for road base and shoulders, driveways, and corrals. Specified amounts of the washed and screened products of this plant were used for concrete aggregate in building the new highway bridge at

Rumsey. Floyd Duncan is superintendent, and nine men are employed. The Sanders pit is located about a mile southwest.

Frank B. Goodwin and son have been loading 300 to 400 cubic yards of gravel per month from the Sanders pit since 1946. The Sanders pit is located on the south bank of Cache Creek in the E$\frac{1}{2}$NE$\frac{1}{4}$ sec. 23, T. 10 N., R. 1 E., M. D., on land owned by E. E. Sanders. The creek bed is a quarter of a mile wide here, and two broad terraces stand five and ten feet above the stream. The gravel on both banks is covered with about 12 feet of silty tan soil. A band of sandy silt about 5 inches thick lies above the gravel in the creek bed and marks the horizon that was covered in flood stage. Goodwin said that the holes they dig each year are filled again in the rainy season when the creek is in flood. The gravel is dug about 7 feet deep with a Hanson dragline equipped with a 30-foot boom and a $\frac{1}{2}$-cubic-yard bucket. Power is supplied by a Hercules gasoline engine. The dragline and engine are mounted on a Studebaker truck chassis. There are no boulders and few cobbles in this pit, and the material looks clean and free from silt. It is used to build driveways and roads. A small amount is used as concrete aggregate for driveways and floors. Goodwin and his son work the pit without additional help. Sanders is paid a royalty on the material removed.

The Joe Schwarzgruber pit is located about half a mile southwest, and the Cache Creek Sand and Gravel Company pit operated by Leroy Kerr is located across the creek about a mile northeast.

Parish Brothers, general contractors of Benicia, are digging sand and gravel from Putah Creek about three-fourths of a mile southeast of the Winters Bridge on land owned by R. W. Rice. The gravel lies on a bar about 200 feet wide on the southeast side of the stream. It is about 3 feet higher than the water level in the dry season. The pebbles are smooth and subangular, 85 percent being less than 1 inch in size, and 50 percent less than a quarter inch. The material is dug 6 to 8 feet deep to a clay stratum with a No. 40 Lorain dragline equipped with a 50-foot boom and a $\frac{3}{4}$-cubic yard bucket. It is loaded into eight 5-cubic-yard dump trucks and hauled about three miles southeast to a Cedar Rapids crushing and screening plant. The loaded trucks are weighed on a 20-ton capacity Fairbanks-Morse platform scale.

At the crushing and screening plant the trucks dump the pit material into a steel hopper 8 feet square on top, with an inverted pyramid-shaped bottom. It is drawn from the bottom of the hopper onto a conveyor belt by a reciprocating feeder. The conveyor belt is 30 inches wide and 50 feet long, and it discharges the material over a 4- by 12-foot double-deck shaker screen. Material larger than 1$\frac{1}{2}$ inches drops into a 10- by 36-inch jaw crusher. Gravel over 1 inch in size slides into a set of 40- by 40-inch rolls. The undersize from both the jaw crusher and rolls is lifted by a wheel-type elevator 8 feet in diameter and discharged onto a conveyor belt 24 inches wide and 25 feet long which returns it to the shaking screen. All the material less than 1 inch in size slides to a conveyor belt stacker 30 inches wide and 50 feet long and is sent to the stock pile. None of the material is washed at this plant. It is all used for road base material for the new Highway 40 on the Fairfield by-pass. The contract calls for 35,000 tons of material. About 1,500 tons is dug per day. C. A. Farnquist is superintendent and 14 men are employed.

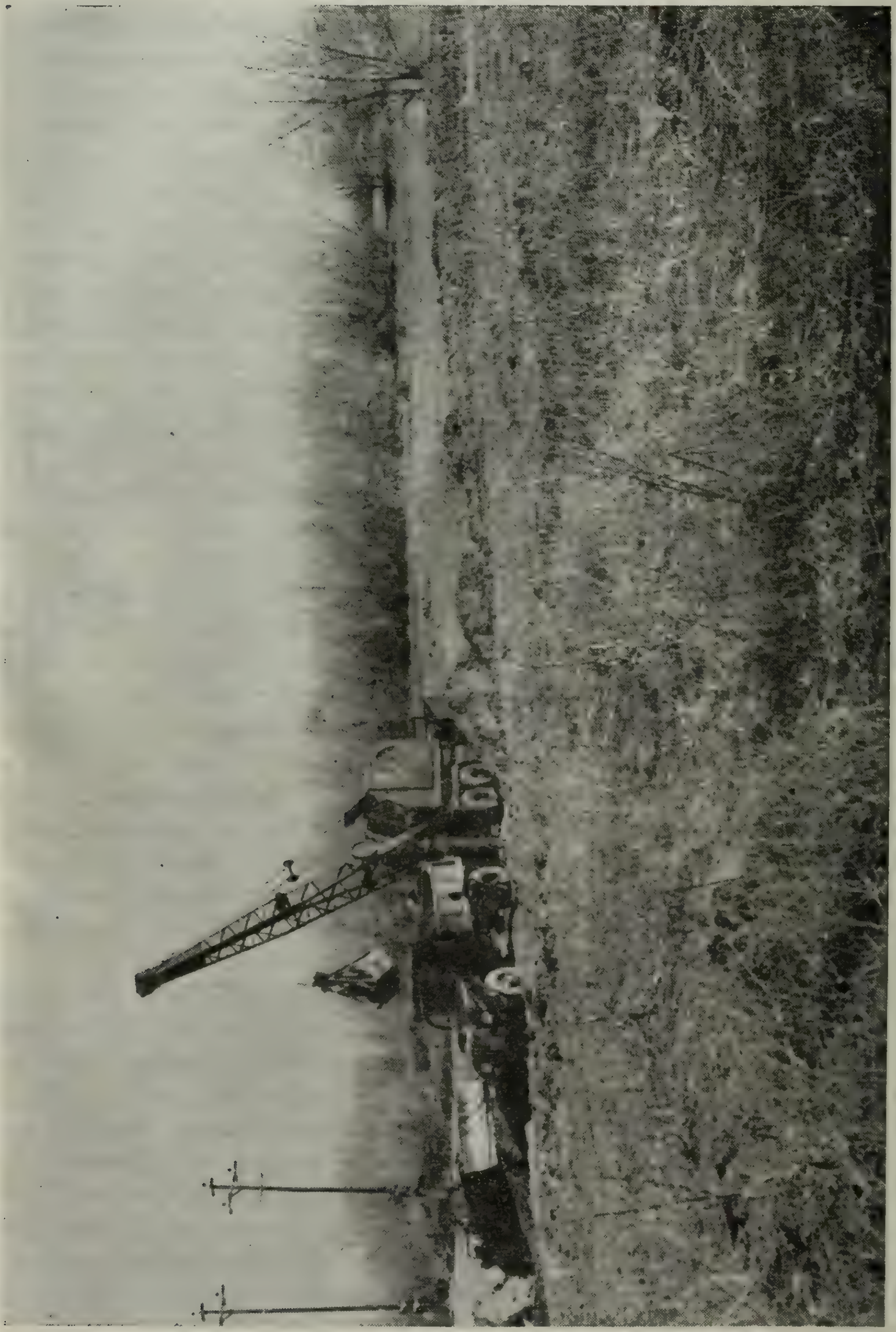

FIGURE 1. State of California, Division of Highways equipment loading gravel from Cache Creek southeast of Woodland.

Joe Schwarzgruber owns and operates a sand and gravel pit on the south side of Cache Creek in sec. 22, T. 10 N., R. 1 E., M. D. The gravel is about a quarter of a mile wide along the creek and lies in two broad terraces from five to ten feet above the water level in the dry season. There are no large boulders and few cobbles. The gravel is dug 8 feet deep to a clay formation with a P & H dragline fitted with a 30-foot boom and a ½-cubic-yard bucket. Four dump trucks of four and five cubic-yards capacity haul the gravel to the screening plant, which is located near the road above the creek. The gravel is dumped into a hopper having a capacity of 20 cubic yards. It is drawn from the hopper by an apron feeder and dropped on a belt conveyor 18 inches wide and 125 feet long, which discharges it over a screen. The minus 1½-inch material drops onto a shaking screen, which separates the material into the following sizes: minus 1½, +¾-inch; minus ¾, +⅜-inch; and minus ⅜-inch. All material is washed with sprays on the screens and the minus ⅜-inch material is dewatered in a drag-type classifier 20 inches wide and 15 feet long. Wash water is pumped from a well 6 inches in diameter and 70 feet deep with a Sterling pump driven by a 7½-horsepower motor. Four bins, each of 30 cubic yards capacity are provided for the screened materials. They are built of 10- by 10-inch timber and have steel-lined floors. The material is drawn from the bins through horizontal sliding steel gates into trucks. The plant has a capacity of 300 cubic yards per day but production averages about 100 cubic yards in 8 hours. About 50 percent of the material is sold for roads and driveways, and 50 percent for concrete aggregate.

Joe Schwarzgruber and his son operate the plant and employ two men. The Sanders pit operated by Frank Goodwin and Yolo County is about a mile northeast. No plants are operating on Cache Creek west of the Schwarzgruber plant, except the Dudley Stephens pit north of Esparto.

Yolo County purchased 1,910 cubic yards of gravel at 35 cents per cubic yard from this plant in the six-month period from July to December, 1948.

The State of California is digging sand and gravel from the dry bed of Cache Creek in sec. 12, T. 10 N., R. 2 E., M. D., on land owned by Frank King. An International TD-14 bulldozer is used to push the material from the pit to feed a Michigan Model TMDT dragline. The dragline is equipped with a 30-foot boom and a ⅜-cubic-yard clam-shell bucket. The gravel is dug in strips about 200 feet long across the creek bed and from 4 to 6 feet deep to a layer of clay. It is loaded onto dump trucks of 4 cubic yards capacity and used to build road shoulders. The material in this pit is mostly sand and small pebbles. Few pieces are over ¾-inch in size.

The Stephens sand and gravel plant is located on the south bank of Cache Creek 1½ miles northeast of Esparto on land owned by C. L. Barr. The gravel is dug from a pit about 100 feet wide, which extends 200 feet northeast to the creek. The gravel is about 4 feet higher than the water level and it is dug about 6 feet below the water to a layer of cobbles. Digging is done with a 1¼-cubic-yard scraper pulled by a double-drum hoist driven by an International TD-18 diesel engine. The hoist and engine are mounted on a steel frame fitted with tractor treads. The scraper pulls the gravel into a 10- by 12-foot wooden hopper, which has an inverted pyramid-shaped bottom. Gravel is drawn through a gate in the bottom onto a portable conveyor belt 20 inches wide and 80 feet long which is mounted on a steel frame. The sand and gravel are discharged from the conveyor into a steel trommel 3 feet in diameter and 6 feet long. The trommel is driven by a V-belt from an Allis-Chalmers, four-cylinder gasoline engine. Material less than 1½ inch in size drops into a 10- by 10- by 10-foot steel bin, from which it is drawn through a horizontal steel gate into trucks. Material over 1½ inches in size slides from the trommel into a wooden bin 10 feet square and 6 feet deep, from which it is drawn into trucks and dumped along the creek bank to prevent further stream erosion. A small amount of this coarse material is sold and used for drains. Stephens employs one man, and the plant has a capacity of 150 cubic yards per day. The material is used for road base and shoulders. Some of the pit run material is used for concrete aggregate to build driveways, sidewalks, and heavy slabs. Yolo County purchased 4,506 cubic yards from this pit in the six month period ending December 1948. It was used for road-base and shoulders.

Sutter County is digging sand and gravel from the bed of Cache Creek in sec. 11, T. 10 N., R. 2 E., M. D., on land owned by Mamie C. Ashley. The creek bed is about a quarter of a mile wide between the levee walls. Trucks are loaded with a P & H dragline equipped with a 20-foot boom and a ¾-cubic-yard bucket. The gravel is mostly fine, few pebbles being over ¾-inch in size, and it is dug about 5 feet deep to a layer of clay. Long strips of heavy hog wire fence material 30 inches wide are laid on the dry creek bed to enable the trucks to travel over it without bogging down.

Some shallow pits in Cache Creek on each side of Road 102 show that sand and gravel has been loaded there recently.

The Valley Gravel Company is operated by Robert Moran of Dixon. Sand and gravel is dug from a bar on Putah Creek just west of the Winters bridge on land owned by Jim Boyce of Winters. The bar is 150 feet wide, 300 feet long, and stands about 3 feet above the water. The gravel is dug with a scoopmobile loader equipped with a ¾-cubic-yard shovel. It is loaded into trucks and used locally for roads, corrals, and as a concrete aggregate for driveways and slabs. The Winters Gravel Service pit adjoins on the west.

Winters Gravel Service is operated by Roger G. Manas, Box 455, Winters, California. Sand and gravel is loaded from a bar on Putah Creek a quarter of a mile southwest of the Winters bridge on land owned by Mrs. Lucy Judy of Winters. The bar is about 100 feet wide, 1,200 feet in length, and stands 3 feet above the water. There are no boulders, and 85 percent of the material is less than 1 inch in size. The gravel is dug to a depth of 7 feet with an Austin-Western dragline equipped with a 30-foot boom and a ¾-cubic-yard bucket. Manas works alone and loads trucks on call. The pit material is used for building roads and driveways. A small amount is used as an aggregrate for concrete driveways and slabs. The property adjoining on the east is operated by Robert Moran of Dixon. The Parish Brothers pit is about half a mile southeast.

The Woodland Transit Concrete Company, a partnership composed of King Lindale, and Robert J. and Thomas W. McCoy, operates a Noble concrete batching plant on the north side of Woodland in SE¼ sec. 20, T. 10 N., R. 2 E., M. D. Washed and screened rock, sand, and gravel is dumped from trucks into a steel-lined concrete bin, which is divided into four 30-cubic-yard compartments. The desired size of material is drawn from the compartments through steel gates onto an 18-inch by 250-foot conveyor belt which runs beneath the bins. It is delivered to four 25-cubic-yard bins at the Noble batching plant. The bins are filled with sand, ¾-inch gravel, 1½-inch rock, and a specified mixture of these sizes for concrete aggregate. The desired materials are weighed into a 2-cubic-yard hopper before they are drawn into the batching trucks. The cement is delivered to the plant in trucks which are emptied into a 3- by 5-foot inverted pyramid-shaped hopper beneath the batching plant. A 10-inch screw conveyor draws the cement from the hopper and feeds a bucket elevator, which delivers it to a 1,200-cubic-foot steel hopper at the same elevation as the aggregate bins. The required amount of cement is weighed into a canvas ''sock'' and is discharged into the transit-mix trucks with the aggregate. Water is pumped from a well 280 feet deep into a tank, from which it is drawn into the 200-gallon tanks mounted on the transit-mix trucks. There are three International trucks of 4½ cubic yards capacity each. They can deliver 150 cubic yards of concrete in an eight hour shift. Concrete made from materials mixed at this plant passed a 2,500 pound compression test in 28 days. Specifications for a recently built school building called for 1,440 pounds of sand, 325 pounds of 1½-inch rock, 1,762 pounds of ¾-inch gravel, 669 pounds of cement, and 0.5 pound of an admix per cubic yard of concrete. It required 26 gallons of water per cubic yard of concrete.

Yolo County is loading sand and gravel from a pit on the south side of Cache Creek in sec. 23, T. 10 N., R. 1 E., M. D., on land owned by E. E. Sanders.

The gravel is dug about 6 feet deep to a clay stratum. It is loaded into dump trucks of 4 cubic yards capacity and used to build roads. The trucks are loaded with a P & H dragline equipped with a 30-foot boom and a ½-cubic-yard bucket. A royalty of five cents per cubic yard was paid to the owner of the pit. In the six months period from July to December, 1948, Yolo County loaded 2,322 cubic yards of road material from this pit.

Yolo County also loads some gravel from pits east of Davis in sec. 24, T. 8 N., R. 2 E., M. D., on land owned by Lloyd Barnett and in sec. 6, T. 8 N., R. 4 E., M. D., on land owned by Fred Smith. The material is used for road base and shoulders in the vicinity of Davis. A small quantity of material is also taken from Cache Creek in sec. 12, T. 10 N., R. 1 E., and sec. 12, T. 10 N., R. 2 E., M. D., and used for road repairs. About 10,000 cubic yards of sand dredged from the Sacramento River in the Clarksburg district is also used by Yolo County for road building each year.

Natural Gas

The most active search for oil or gas in Yolo County has been in the Dunnigan Hills area about 12 miles northwest of Woodland, the Fairfield Knolls area northeast of Winters, and in the Rumsey Hills area east of Rumsey. The Texas Company drilled five wells in T. 11 N., R. 1 W., M. D., in 1947 and two of them were successfully completed. A well in sec. 22, T. 11 N., R. 1 W., struck gas between 2,400 and 2,620 feet in depth in a formation thought to be lower Eocene. The Fairfield Knolls gas field[10] is located in secs. 29 and 32, T. 9 N., R. 1 E., M. D., six miles northeast of Winters. A series of small hills projecting a few feet above the valley alluvium and exposing the Red Bluff and Tehama sediments, is the only evidence of folding in the vicinity. Reflection seismograph work during 1935-36 and 1937 resulted in the definition of an anticlinal fold of low structural relief trending northwestward. The Standard Oil Company Hooper No. 1 well located in the NE¼ sec. 32, T. 9 N., R. 1 E., M. D., found gas in commercial quantities between 3,675 and 3,714 feet in August 1937. Drilling was continued to a depth of 5,181 feet without finding additional gas-bearing sands. The well was plugged to 3,400 feet, redrilled to 3,700 feet, and 6⅝-inch diameter casing cemented at 3,669 feet. A generalized stratigraphic sequence in the field based on the log of the well shows: upper Pliocene (Tehama formation), a few inches to 2,563 feet; upper and middle Eocene (includes recognized Markley, Domengine, and Capay formations), 2,563 to 4,170+ feet; upper Cretaceous (Chico series) 4,170+ to 5,181 feet. This well is now connected to the Rio Vista gas line. Analysis of gas from this well shows 0.14 percent hydrogen, 7.88 percent nitrogen, and 91.98 percent methane.

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[10] Kirby, J. M., Fairfield Knolls gas field and Rumsey Hills area: California Div. Mines Bull. 118, pp. 599-605, 1943.

A second well drilled by the Standard Oil Company located in the SE¼ sec. 29, T. 9 N., R. 1 E., M. D., called the Corcoran No. 1 was completed September 19, 1939, at a depth of 3,682 feet. The top of the Hooper sand was logged at 3,682 feet and a 6⅝-inch diameter casing was cemented at 3,634 feet. This well is also connected to the Rio Vista gas line. The Shell Oil Company gas well in lot 7, sec. 18, T. 8 N., R. 1 E., M. D., drilled in 1947 is shut in.

The Rumsey Hills anticline[11] trends northwestward along the western foothill belt from Capay in T. 10 N., R. 2 W., M. D., to the northwest corner of T. 13 N., R. 3 W., M. D., in Colusa County, a distance of about 22 miles. The presence of natural gas in springs throughout the area called attention to the possibilities of developing commercial wells. Attempts to develop oil or gas through drilling dates back to the period from 1900 to 1903 when four wells were drilled in sec. 7, T. 12 N., R. 3 W., M. D., in Colusa County without favorable results. Several holes have been drilled in recent years along this anticline in T. 12, 13 N., R. 3 W., M. D., ranging from 570 to 6,764 feet in depth without developing commercial amounts of gas or oil.

A wildcat well drilled midway between Winters and Madison in sec. 28, T. 9 N., R. 1 W., M. D., was abandoned at a depth of 5,486 feet. Another wildcat well in the southeastern portion of the county in sec. 10, T. 6 N., R. 3 E., was abandoned at a depth of 4,912 feet.

There were 444 acres included in the proved acreage of Yolo County, December 31, 1947.[12]

Quicksilver

The quicksilver deposits of Yolo County are located in the northwestern corner of the county near the common border with Lake and Napa Counties. Cinnabar and metacinnabar occur in fractures and small seams and disseminated in hard, black, silicified Franciscan sediments in or near intrusive peridotite which has been altered to serpentine.[13]

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[11] Kirby, J. M., Rumsey Hills area: California Div. Mines Bull. 118, pp. 601-605, 1943.

[12] Proved acreage by counties, December 31, 1947: California Div. Oil and Gas, Summary of Operations California Oil Fields, vol. 33, no. 2, p. 82, 1947.

[13] Jenkins, O. P., Economic mineral map of California, No. 1—Quicksilver: California Div. Mines, 1939.

The Harrison (New England, Ruby, and January) mine is located in secs. 26 and 35, T. 12 N., R. 5 W., M. D. It is owned by Madge J. Harrison and associates. It had a small production prior to 1900 but its period of greatest activity was during World War I. A concentrating plant consisting of a coarse crusher, ball mill, Wilfley, and Diester tables was built in 1918 to treat 150 tons of ore per day. Production statistics compiled by the U. S. Geological Survey in 1945 [14] credit the property with a production of 220 flasks in 1919 and a total production of 374 flasks to the end of 1945. The property was last operated by the Yo-Lake Mineral Company in 1943. It is described in an earlier report.[15]

The Reed (California) mine includes 370 acres of land in secs. 23, 24, 25, and 26, T. 12 N., R. 5 W., M. D., for which a patent was issued to the California Quicksilver Mining Company on October 2, 1875. The first production of 995 flasks was made in 1873. The mine was credited with a production of 9,648 flasks by 1880 and had a total production of 21,177 by the end of 1945.[16]

The Bradley Mining Company, 425 Crocker Building, San Francisco, acquired a grant of the mineral rights to the Reed mine from George A. Newhall and his wife on June 11, 1940, and a new period of activity commenced. During their operation Charles Boyd of Monticello was superintendent, and over 11,000 flasks of quicksilver were produced during the war years. Operations were suspended in November 1947, because of the increased cost of mining and the low price for quicksilver. A description of the property is given in an earlier publication.[17]

MINERAL COMMODITY SURVEY

The Spreckels Sugar Company at Woodland and the American Crystal Sugar Company at Clarksburg were the principal consumers of minerals in Yolo County in 1948. They used the following amounts of these minerals:

Diatomite—334,500 pounds. It was a processed product which was calcined and fluxed. The shape of the diatoms is important in the filtering process and not all types of California diatomite are suitable. It is used in a powdered form. The material was purchased from the Johns-Manville Products Corporation at Lompoc and from the Dictolite Company of Terrebonne, Oregon.

The sugar refining process using vertical kilns requires a dense, high-grade limestone which will not shatter and clog the kilns when it is burned. It is required in lumps from 1½ to 6 inches in size. The suitability can be determined only by trial, but the chemical analysis must run over 98 percent $CaCO_3$ and less than 0.1 percent iron, 0.2 percent magnesium, and 0.5 percent silica. The limestone used in the sugar refineries of Yolo County amounted to 32,000 tons in 1948. It was purchased from the California Rock and Gravel Company at Auburn, and the El Dorado Limestone Company at Shingle Springs. In the refining processes the CO_2 is returned to the calcines, and the resulting chalklike product is used on the beet fields as a soil conditioner.

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[14] Quicksilver production of Knoxville District: U. S. Geol. Survey Pamph., January 1947.

[15] Ransome, A. L., and Kellogg, J. L., Quicksilver resources of California: California Jour. Mines and Geology, vol. 35, p. 475, 1939.

[16] Quicksilver production of Knoxville district: U. S. Geol. Survey Pamph., January 1947.

[17] Averill, C. V., Reed mine: California Jour. Mines and Geol., vol. 39, p. 322, 1943.

*Tabulated list of mining properties in Yolo County, 1948.**

Number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B & M		
3	Ashley gravel pit	Mamie C. Ashley	11	10N	2E	M.D.	Sand and gravel	Sutter County operation, Cache Creek.
4	Barnett gravel pit	Lloyd Barnett	1	8N	3E	M.D.	Sand and gravel	East of Davis, Yolo County operations.
5	Cache Creek Sand and Gravel Company	Leroy Kerr, Box 34, Yolo, California	14	10N	1E	M.D.	Sand and gravel	
1	Harrison (New England, Ruby, and January) mine	Madge J. Harrison, et al.	26, 35	12	5W	M.D.	Quicksilver	Idle. B. 27, p. 117; B. 78, p. 204; B. 78, p. 346; R. 12, p. 363; R. 13, p. 598; R. 14, p. 369; R. 35, p. 475.
6	King gravel pit	Frank King	12	10N	2E	M.D.	Sand and gravel	Pit is operated by California State Div. of Highways.
2	Reed (California) mine	Bradley Mining Co., 425 Crocker Bldg., San Francisco	23, 24, 25, 26	12N	5W	M.D.	Quicksilver	Idle. B. 27, p. 117; B. 78, p. 205; R. 13, p. 604; R. 14, p. 369; R. 28, pp. 318, 319, 326; R. 39, p. 322.
7	Rice gravel pit	R. W. Rice, Winters, California	28	8N	1W	M.D.	Sand and gravel	Pit is located on Putah Creek about ¾ mi. southeast of Winters bridge. Operated by Parish Brothers, Contractors, Benicia, California.
8	Sanders pit	E. E. Sanders	23	10N	1E	M.D.	Sand and gravel	Yolo County is digging gravel at this pit.

9	Sanders pit	E. E. Sanders	23	10N	1E	M.D.	Sand and gravel	South bank of Cache Creek.
								Frank B. Goodwin and Son also load gravel from Sanders pit a few hundred feet southwest of the Yolo County operation.
10	Schwarzgruber sand and gravel plant	Joe Schwarzgruber	22	10N	1E	M.D.	Sand and gravel	South side of Cache Creek.
11	Smith gravel pit	Fred Smith	6	8N	4E	M.D.	Sand and gravel	Yolo County operations near Davis.
12	Stephens sand and gravel plant	C. L. Barr					Sand and gravel	South bank of Cache Creek 1½ mi. northeast of Esparto Land, owned by C. L. Barr.
13	Valley Gravel Co. pit	Jim Boyce, Winters, California	22	8N	1W	M.D.	Sand and gravel	Operated by Robert Moran, Dixon, California; Putah Cr. near Winters Bridge.
14	Winters Gravel Service pit	Mrs. Lucy Judy, Winters, California	28	8N	1W	M.D.	Sand and gravel	On Putah Creek ¼ mi. S.W. of Winters bridge.
15	Woodland Transit Concrete Co.	(A partnership) King Lindale, Robert J. and Thomas W. McCoy	SE¼, 20	10N	2E	M.D.	Concrete, Concrete mix.	Batching concrete aggregate to specifications and delivering it in Transit-Mix trucks.

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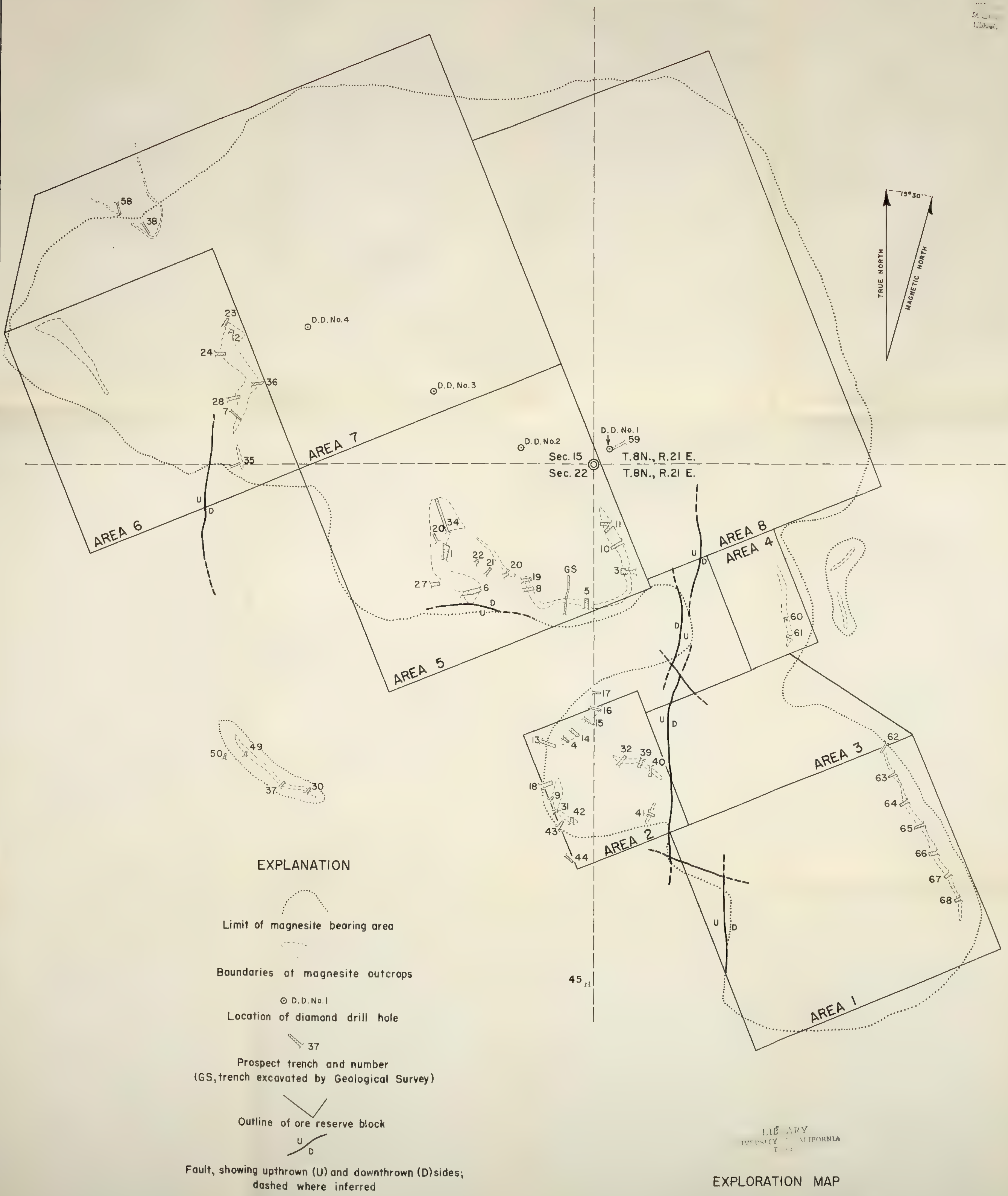
* References are to reports and bulletins published by the California State Division of Mines.

The sugar refineries used 266,400 pounds of commercial grade soda ash in 1948. It contained not less than 58 percent Na_2O and it was purchased in granular form, packed in 100 pound bags. The soda ash is used to precipitate the lime and it reduces the amount carried in solution. Some 26,650 pounds of caustic soda were used in the refineries in 1948. It was the ordinary commercial grade that is marketed in 400 pound metal drums.

One sugar refinery used 84,620 pounds of sulphur in 1948. It was purchased in crude lump form containing $99\frac{1}{2}$ percent sulfur. Another company used 60,000 pounds of liquid sulphur dioxide in 1948. It was delivered in tank cars.

23300 3-50 2,500

Pocket #3


58
38
23
12
24
36
28
7
35
D.D. No. 4
D.D. No. 3
D.D. No. 2
D.D. No. 1
59
Sec. 15
Sec. 22
T.8N., R.21 E.
T.8N., R.21 E.
AREA 7
AREA 6
AREA 5
AREA 8
AREA 4
AREA 3
AREA 2
AREA 1
U
D
20
34
1
22
21
20
19
8
GS
5
11
10
3
27
6
60
61
17
16
15
13
4
14
32
39
40
18
9
31
42
43
41
44
62
63
64
65
66
67
68
45
50
49
37
30
15°30'
TRUE NORTH
MAGNETIC NORTH

EXPLANATION

Limit of magnesite bearing area

Boundaries of magnesite outcrops

⊙ D.D. No. 1
Location of diamond drill hole

37
Prospect trench and number
(GS, trench excavated by Geological Survey)

Outline of ore reserve block

U
D
Fault, showing upthrown (U) and downthrown (D) sides;
dashed where inferred

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EXPLORATION MAP
NEEDLES MAGNESITE DEPOSIT
NEEDLES, CALIFORNIA

100 0 100 200 300 FEET

Geology by C.J.Vitaliano, March, 1943

EXPLANATION

QUATERNARY

- Qal — Alluvium

TERTIARY (?)

- Tv — Volcanic agglomerate and latitic flows
- Tchd — Cherty dolomite
- Tds, m — Thin-bedded dolomite, shale, and tuff, includes magnesite bearing horizon shown by (m)
- Ta — Andesite tuff

PRE-CAMBRIAN

- p€g — Gneiss and granite

Fault showing upthrown (U) and downthrown (D) sides dashed where inferred

Contact

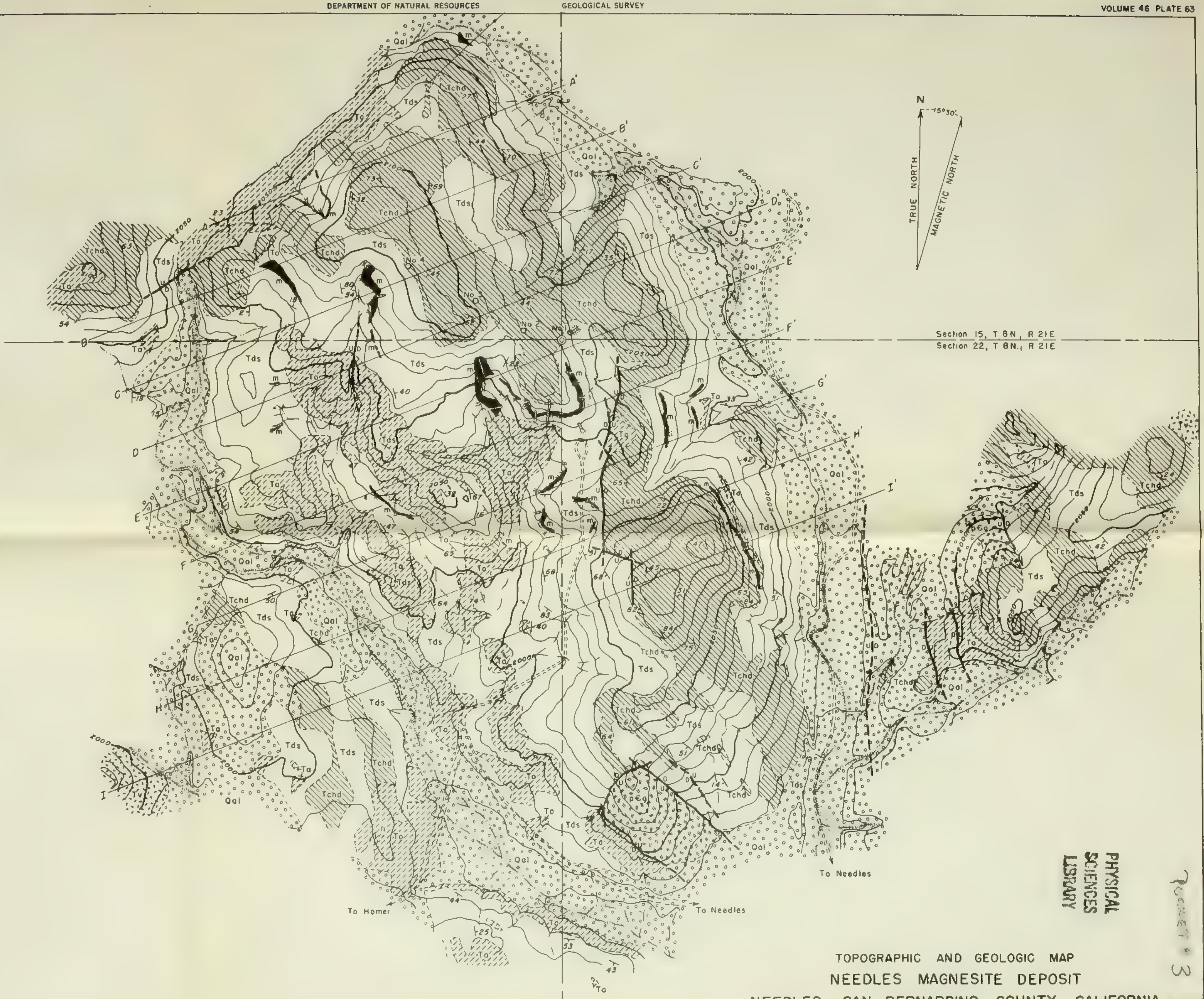
Strike and dip of beds

Strike and dip of overturned beds

Trenches

No.2 Diamond drill hole

Quarter section corner


N
15°30'
TRUE NORTH
MAGNETIC NORTH
A
A'
B
B'
C
C'
D
D'
E
E'
F
F'
G
G'
H
H'
I
I'
Section 15, T 8N, R 21E
Section 22, T 8N, R 21E
No 2
No 4
Qal
Tv
Tchd
Tds
Ta
p€g
m
U
D
2000
2050
2100
To Needles
To Homer
To Needles

TOPOGRAPHIC AND GEOLOGIC MAP
NEEDLES MAGNESITE DEPOSIT
NEEDLES, SAN BERNARDINO COUNTY, CALIFORNIA

0 200 400 600 800 FEET

Contour interval 10 feet

Datum is mean sea level

C J Vitaliano and A J Bodenlos March, 1943

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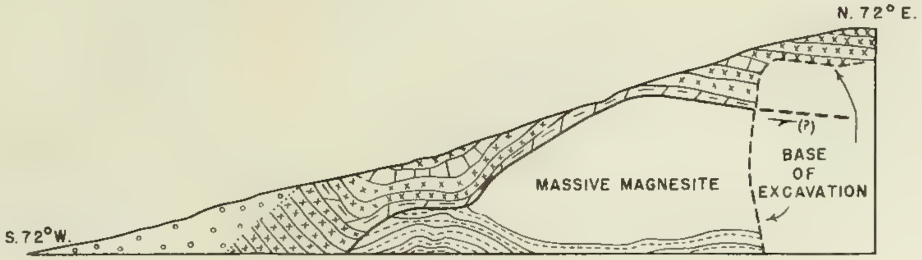
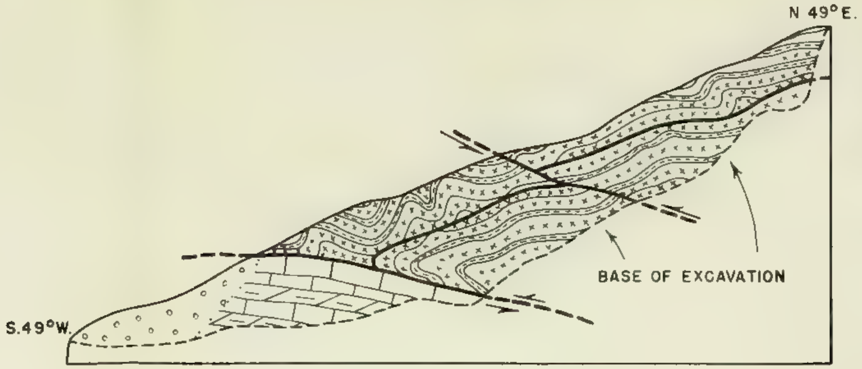
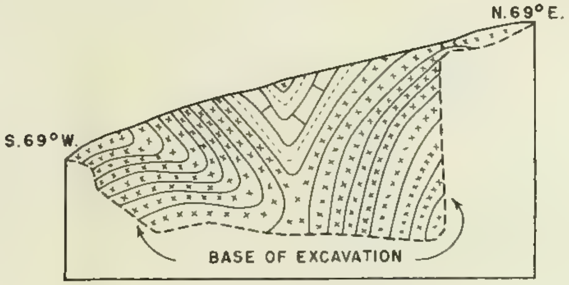

N. 72° E.
S. 72° W.
MASSIVE MAGNESITE
(?)
BASE OF EXCAVATION

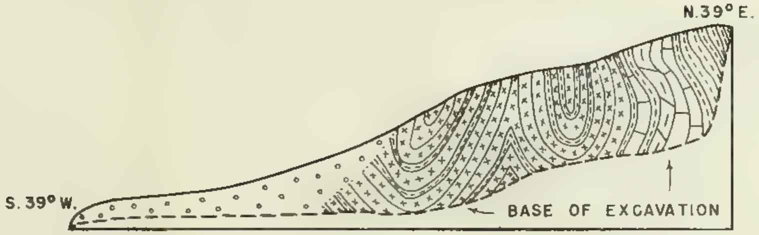
TRENCH NO. 11


N 49° E.
S. 49° W.
BASE OF EXCAVATION

TRENCH NO. 7


N. 69° E.
S. 69° W.
BASE OF EXCAVATION

TRENCH NO 31


N. 39° E.
S. 39° W.
BASE OF EXCAVATION

TRENCH NO. 30

EXPLANATION

QUATERNARY
- Alluvium

TERTIARY
- Limestone
- Dolomite
- Magnesite
- Shale

Contact

Long profile of the base of trench

Fault
Showing relative movement,
(dashed where inferred)

GEOLOGIC SECTION EXPOSED ALONG TRENCHES

NEEDLES MAGNESITE DEPOSIT

NEEDLES, SAN BERNARDINO COUNTY, CALIFORNIA.

0 5 10 20 FEET

Geology by C. J. Vitaliano, March, 1943

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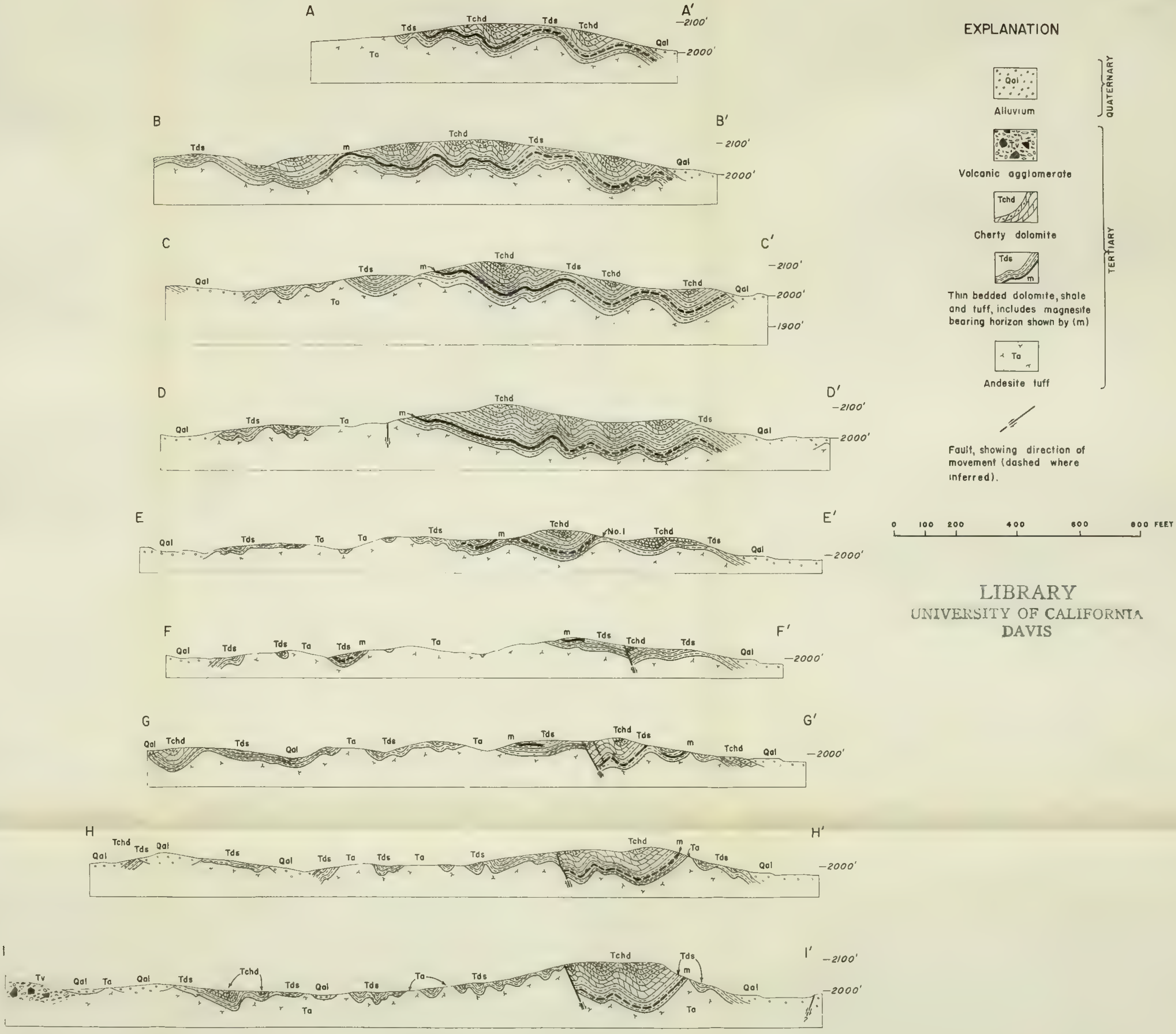
A
A'
Tds
Tchd
Tds
Tchd
Ta
Qal
2100'
2000'
B
B'
Tds
m
Tchd
Tds
Qal
2100'
2000'
C
C'
Qal
Tds
m
Tchd
Tds
Tchd
Tchd
Qal
Ta
2100'
2000'
1900'
D
D'
Qal
Tds
Ta
m
Tchd
Tds
Qal
2100'
2000'
E
E'
Qal
Tds
Ta
Ta
Tds
m
Tchd
No. 1
Tchd
Tds
Qal
2000'
F
F'
Qal
Tds
Tds
Ta
Tds
m
Ta
m
Tds
Tchd
Tds
Qal
2000'
G
G'
Qal
Tchd
Tds
Qal
Ta
Tds
Ta
m
Tds
Tchd
Tds
m
Tchd
Qal
2000'
H
H'
Tchd
Qal
Tds
Qal
Tds
Qal
Tds
Ta
Tds
Ta
Tds
Tchd
m
Ta
Tds
Qal
2000'
I
I'
Tv
Qal
Ta
Qal
Tds
Tchd
Tds
Qal
Tds
Ta
Tds
Tchd
Tds
m
Ta
Ta
Qal
2100'
2000'
EXPLANATION
Qal
Alluvium
QUATERNARY
Tv
Volcanic agglomerate
Tchd
Cherty dolomite
Tds
m
Thin bedded dolomite, shale and tuff, includes magnesite bearing horizon shown by (m)
Ta
Andesite tuff
TERTIARY
Fault, showing direction of movement (dashed where inferred).
0
100
200
400
600
800 FEET

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GEOLOGIC SECTIONS
OF THE
NEEDLES MAGNESITE DEPOSIT

C. J. Vitaliano & A. J. Bodenlos March, 1943

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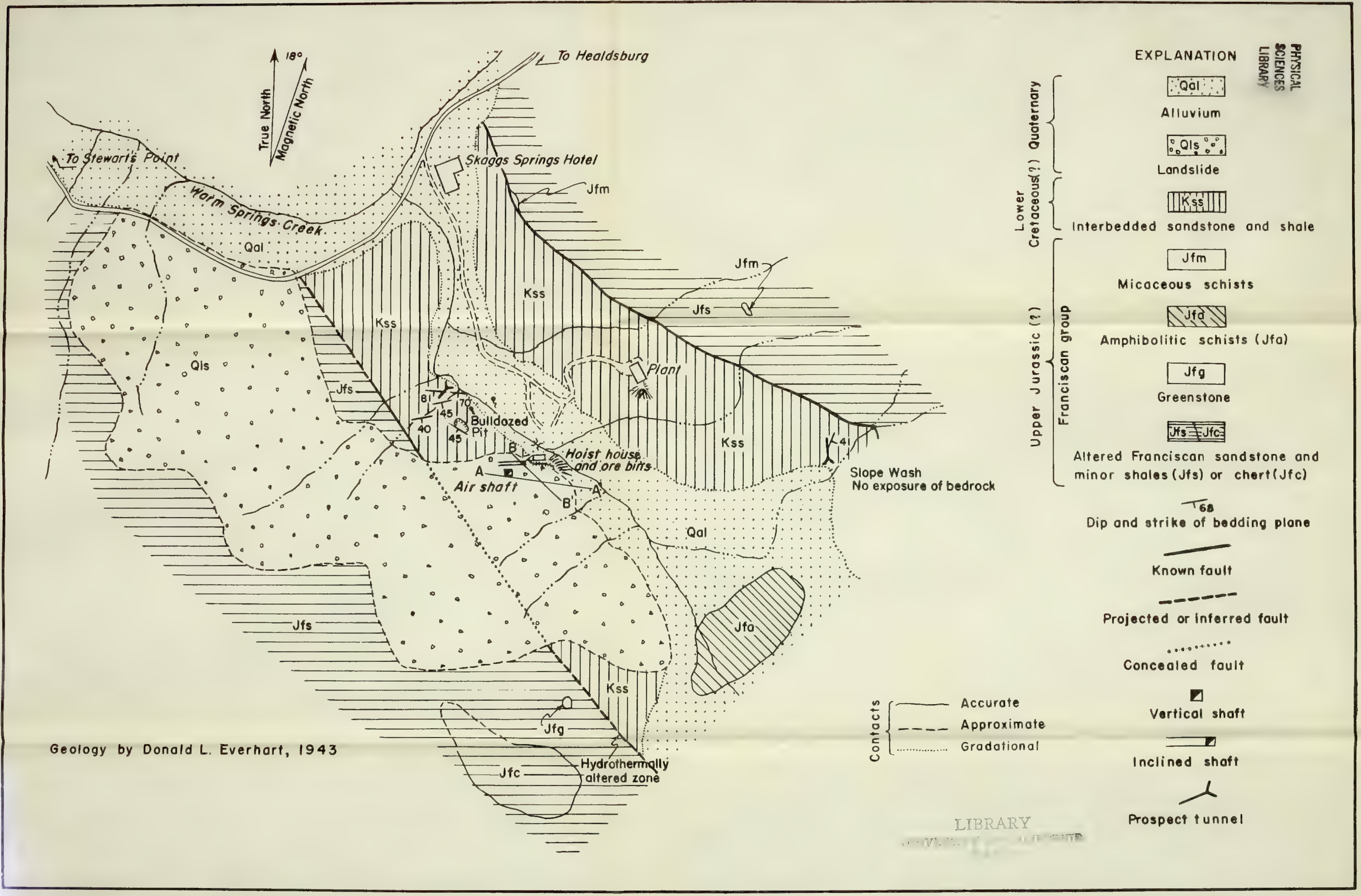
To Healdsburg
18°
True North
Magnetic North
To Stewart's Point
Warm Springs Creek
Skaggs Springs Hotel
Jfm
Qal
Kss
Kss
Jfm
Jfs
Qls
Jfs
Plant
81
70
45
40
45
Bulldozed Pit
B
Hoist house and ore bins
A
Air shaft
A
B
Kss
41
Slope Wash
No exposure of bedrock
Qal
Jfs
Jfa
Kss
Jfg
Jfc
Hydrothermally altered zone
Geology by Donald L. Everhart, 1943
Contacts
Accurate
Approximate
Gradational
EXPLANATION
Quaternary
Qal
Alluvium
Qls
Landslide
Lower Cretaceous (?)
Kss
Interbedded sandstone and shale
Upper Jurassic (?)
Franciscan group
Jfm
Micaceous schists
Jfa
Amphibolitic schists (Jfa)
Jfg
Greenstone
Jfs
Jfc
Altered Franciscan sandstone and minor shales (Jfs) or chert (Jfc)
68
Dip and strike of bedding plane
Known fault
Projected or inferred fault
Concealed fault
Vertical shaft
Inclined shaft
Prospect tunnel

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GEOLOGIC SKETCH MAP OF THE VICINITY OF THE SKAGGS SPRINGS QUICKSILVER MINE, SONOMA COUNTY, CALIFORNIA

Approximate scale
0 400 800 1200 Feet

Enlarged 4X from geology plotted on aerial photographs (Scale: $\frac{1}{20,000}$)

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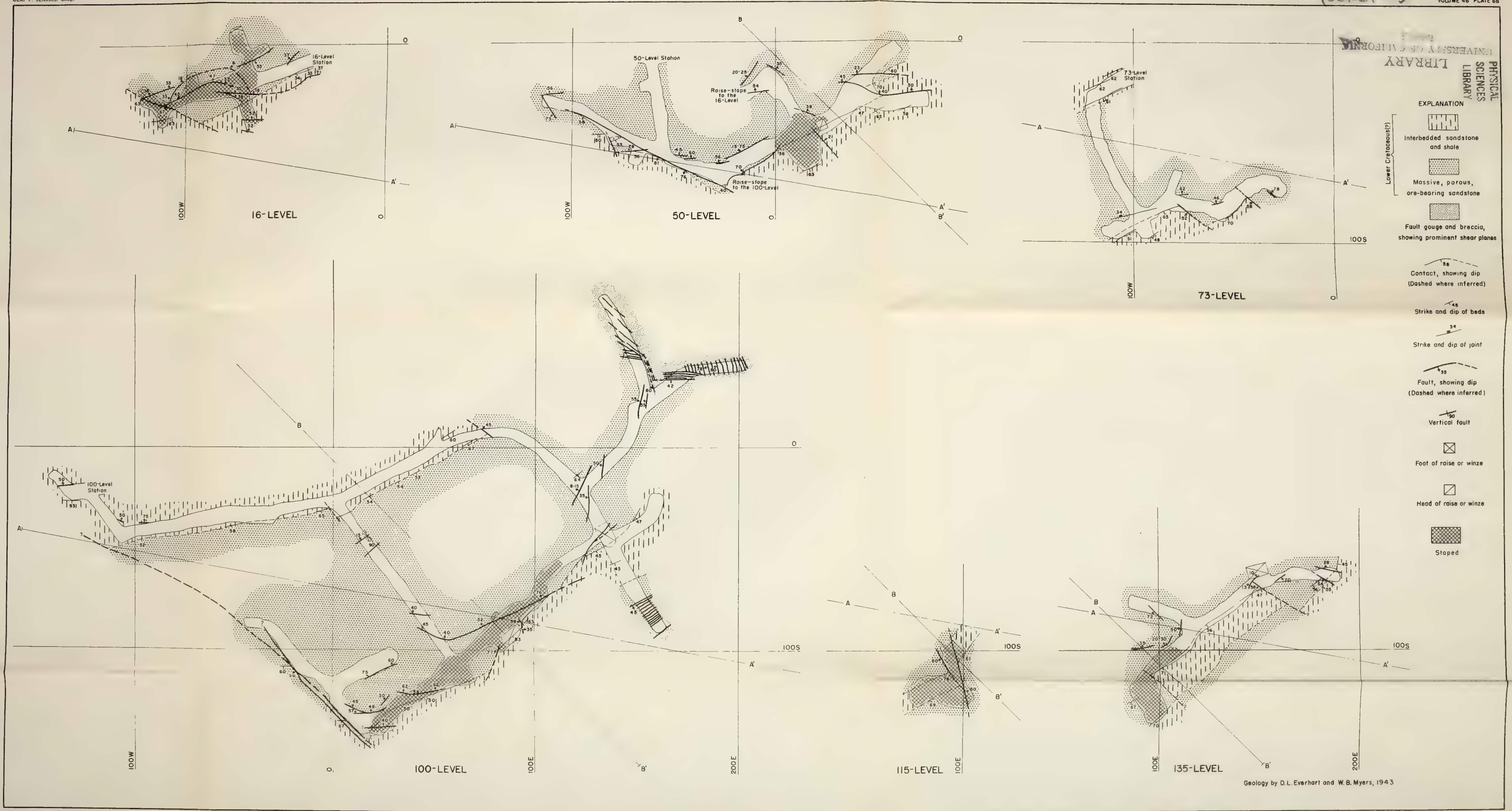
16-LEVEL
16-Level Station
50-LEVEL
50-Level Station
Raise-stope to the 16-Level
Raise-stope to the 100-Level
73-LEVEL
73-Level Station
100-LEVEL
100-Level Station
115-LEVEL
135-LEVEL
100W
0
100E
200E
100S
A
A'
B
B'
EXPLANATION
Lower Cretaceous(?)
Interbedded sandstone and shale
Massive, porous, ore-bearing sandstone
Fault gouge and breccia, showing prominent shear planes
Contact, showing dip (Dashed where inferred)
Strike and dip of beds
Strike and dip of joint
Fault, showing dip (Dashed where inferred)
Vertical fault
Foot of raise or winze
Head of raise or winze
Stoped
Geology by D.L. Everhart and W.B. Myers, 1943

GEOLOGIC MAPS OF THE UNDERGROUND LEVELS, SKAGGS SPRINGS QUICKSILVER MINE, SONOMA COUNTY, CALIFORNIA

0 10 20 30 40 50 Feet

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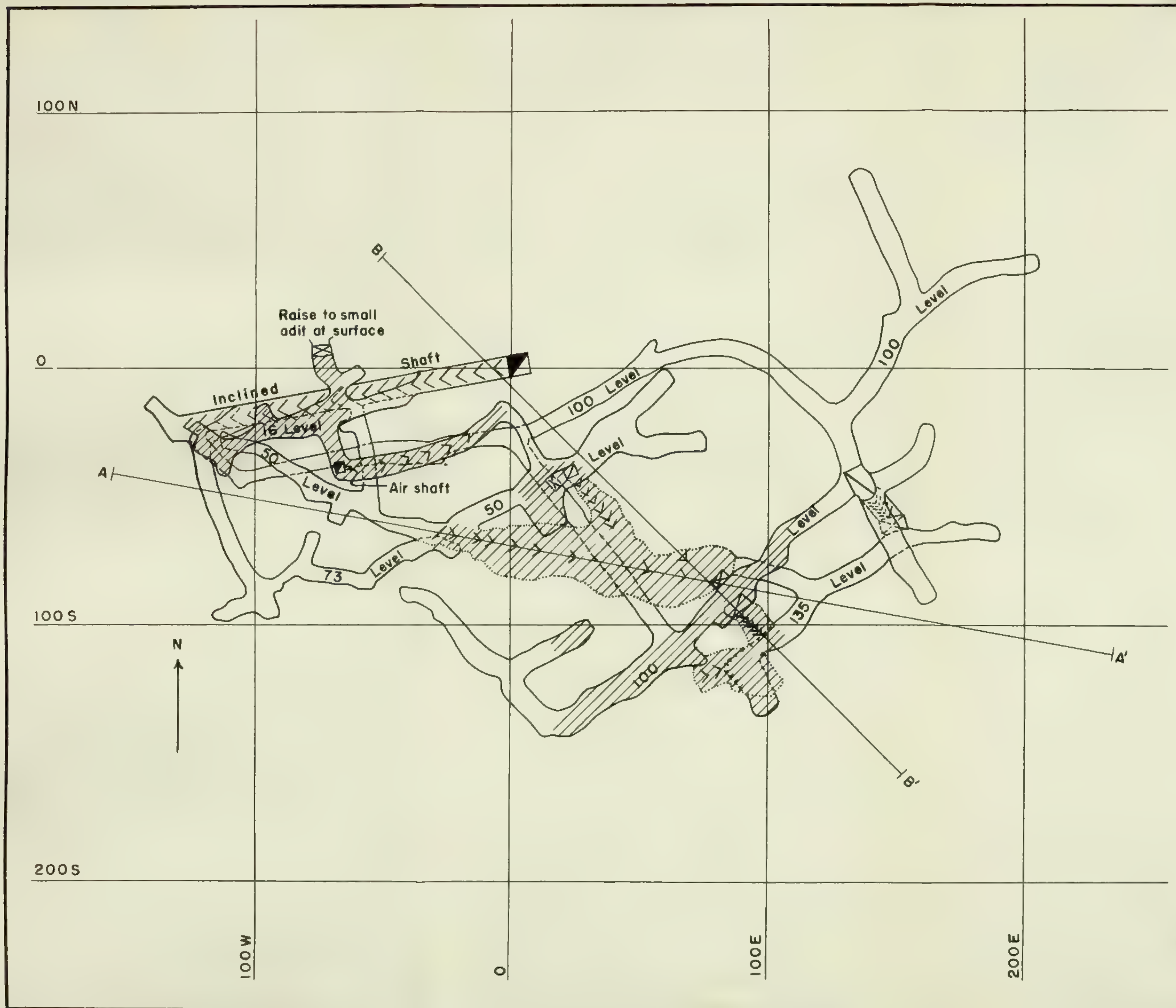
100 N
0
100 S
200 S
100 W
0
100 E
200 E
N
A
A'
B
B'
Raise to small adit at surface
Shaft
Inclined
16 Level
50
Level
Air shaft
100 Level
Level
50
73
Level
100
Level
100
Level
135
Level
100

EXPLANATION

73 Level

Workings (dashed where lying below others). Number of the level indicates elevation in feet below the inclined shaft collar.

▨ Stoped area

▨ Stope with walls approximately located

>>>> Chevrons show slope of floor; point downward at elevation intervals of 5 feet

◩ Shaft from the surface

◩ Head of raise or winze

☒ Foot of raise or winze

⊢—⊣ Line of cross section

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COMPOSITE MAP OF UNDERGROUND WORKINGS, SKAGGS SPRINGS QUICKSILVER MINE, SONOMA COUNTY, CALIFORNIA

50 0 50 100 150 Feet

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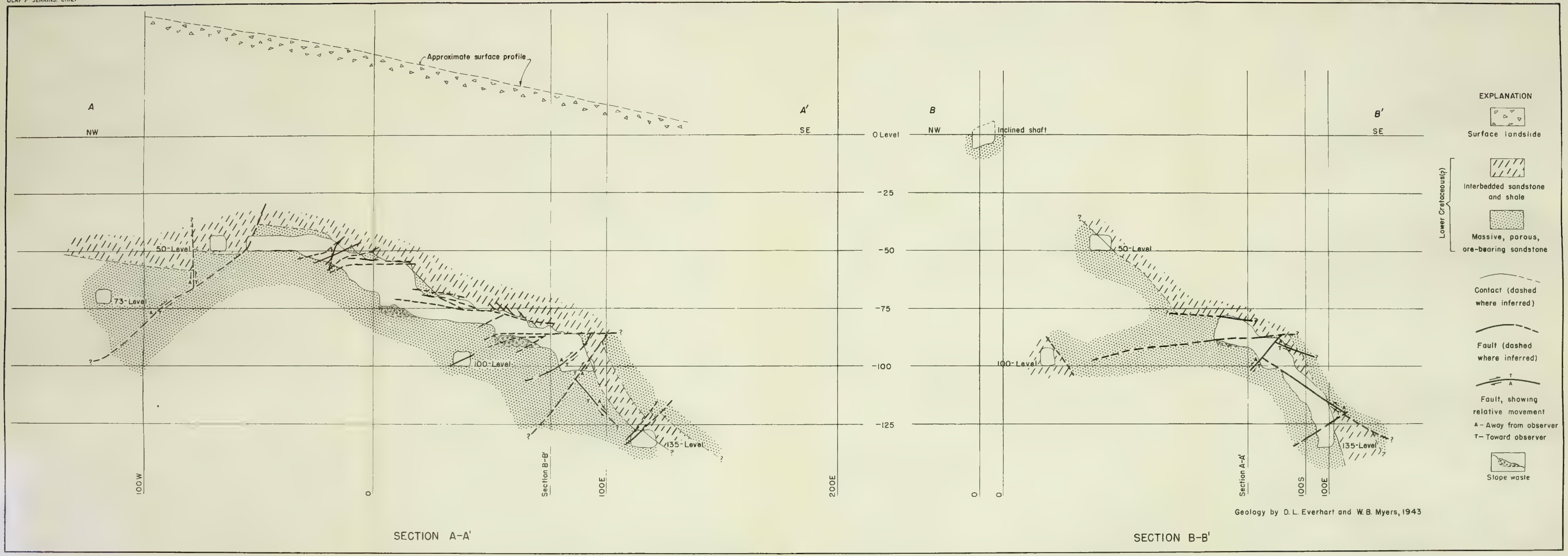
Approximate surface profile
A
NW
A'
SE
B
NW
B'
SE
Inclined shaft
0 Level
-25
-50
-75
-100
-125
50-Level
73-Level
100-Level
135-Level
A
T
?
100W
0
Section B-B'
100E
200E
0
0
Section A-A'
100S
100E
EXPLANATION
Surface landslide
Lower Cretaceous(?)
Interbedded sandstone and shale
Massive, porous, ore-bearing sandstone
Contact (dashed where inferred)
Fault (dashed where inferred)
Fault, showing relative movement
A – Away from observer
T – Toward observer
Stope waste
Geology by D. L. Everhart and W. B. Myers, 1943
SECTION A-A'
SECTION B-B'

VERTICAL SECTIONS THROUGH SKAGGS SPRINGS QUICKSILVER MINE, SONOMA COUNTY, CALIFORNIA

0 10 20 30 40 50 Feet

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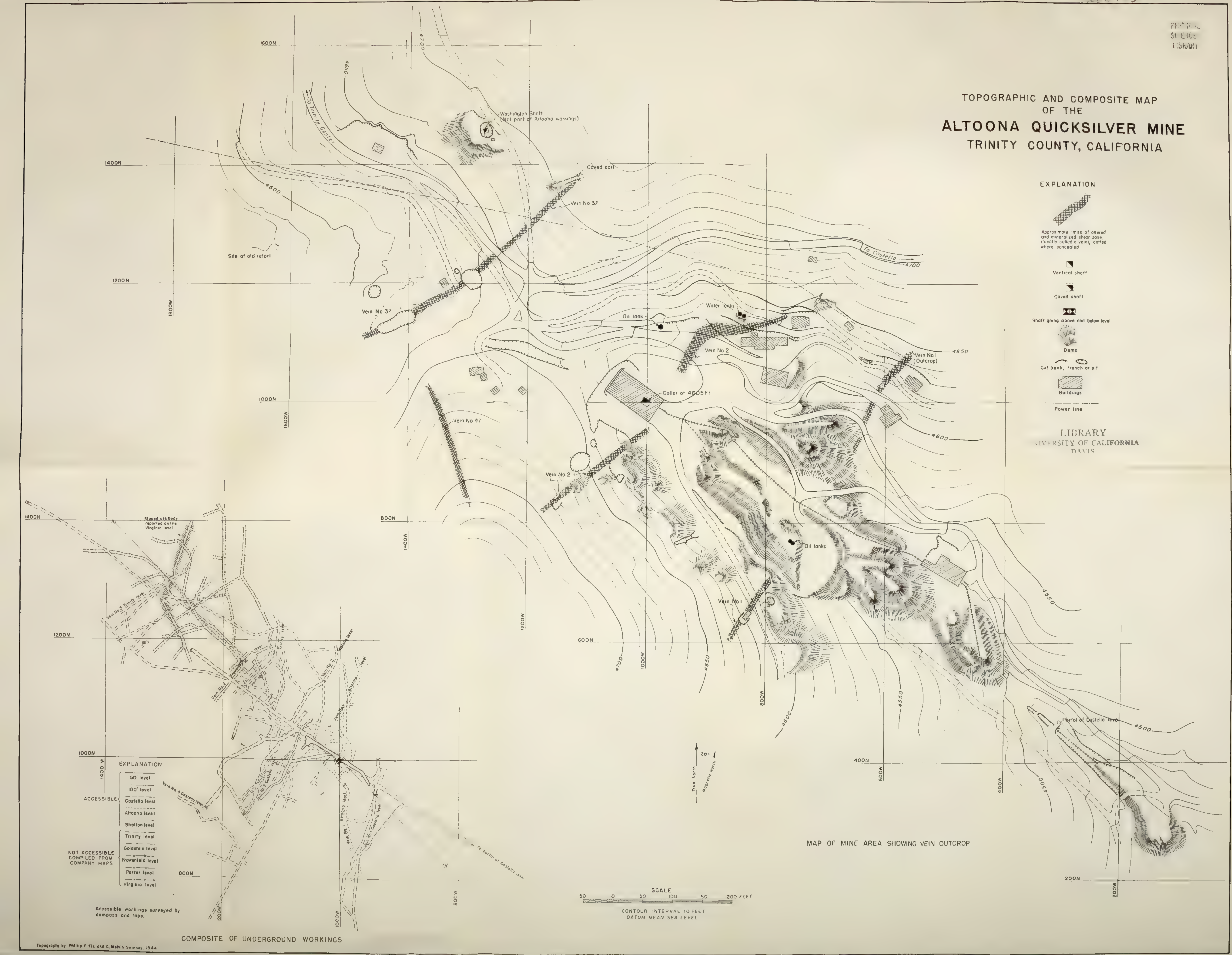
TOPOGRAPHIC AND COMPOSITE MAP
OF THE

ALTOONA QUICKSILVER MINE

TRINITY COUNTY, CALIFORNIA


1600N
1400N
1200N
1000N
800N
600N
400N
200N
1800W
1600W
1400W
1200W
1000W
800W
600W
400W
200W
4700
4650
4600
4550
4500
To Trinity Center
Washington Shaft
(Not part of Altoona workings)
Caved adit
Vein No 3?
Site of old retort
Vein No 3?
Oil tank
Water tanks
Vein No 2
To Castella
Vein No 1
(Outcrop)
Collar at 4605 Ft
Vein No 4?
Vein No 2
Oil tanks
Vein No 1
Portal of Castella level
True North
Magnetic North
20°
Stoped ore body reported on the Virginia level
Vein No 3 Trinity level
Vein No 1 Frowenfeld level
Vein No 2 Castella level
Altoona level
Vein No 4 Castella level
Vein No 2 Castella level
Vein No 1 Altoona level
Vein No 1 Castella level
To Portal of Castella level
'A'
1000N
1400 W
800N
1200W
1000W
800W

EXPLANATION

▨	Approximate limits of altered and mineralized shear zone, (locally called a vein), dotted where concealed
◪	Vertical shaft
◪	Caved shaft
⧖	Shaft going above and below level
	Dump
⌒ ⬭	Cut bank, trench or pit
▨	Buildings
—·—·—	Power line

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MAP OF MINE AREA SHOWING VEIN OUTCROP

SCALE
50 0 50 100 150 200 FEET

CONTOUR INTERVAL 10 FEET
DATUM MEAN SEA LEVEL

EXPLANATION

ACCESSIBLE
- 50' level
- 100' level
- Castella level
- Altoona level
- Shelton level

NOT ACCESSIBLE COMPILED FROM COMPANY MAPS
- Trinity level
- Goldstein level
- Frowenfeld level
- Porter level
- Virginia level

Accessible workings surveyed by compass and tape.

COMPOSITE OF UNDERGROUND WORKINGS

Topography by Phillip F Fix and C. Melvin Swinney, 1944

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GEOLOGIC LEVEL MAPS AND CROSS SECTIONS OF THE
ALTOONA QUICKSILVER MINE
TRINITY COUNTY, CALIFORNIA

50 0 50 100 150 FEET
SCALE

EXPLANATION

hd
Porphyritic hornblende diorite

fd
Porphyritic feldspathic diorite

ar
Altered rock

s
Serpentine

Cinnabar veinlets

Gradational contact

Fault or shear, showing dip
(Dashed where approximately located—dotted where concealed) U-upthrown side D-downthrown side

Vertical fault or shear

Shaft going above and below levels

Inclined workings
(Chevrons point down)

☒
Foot of raise or winze

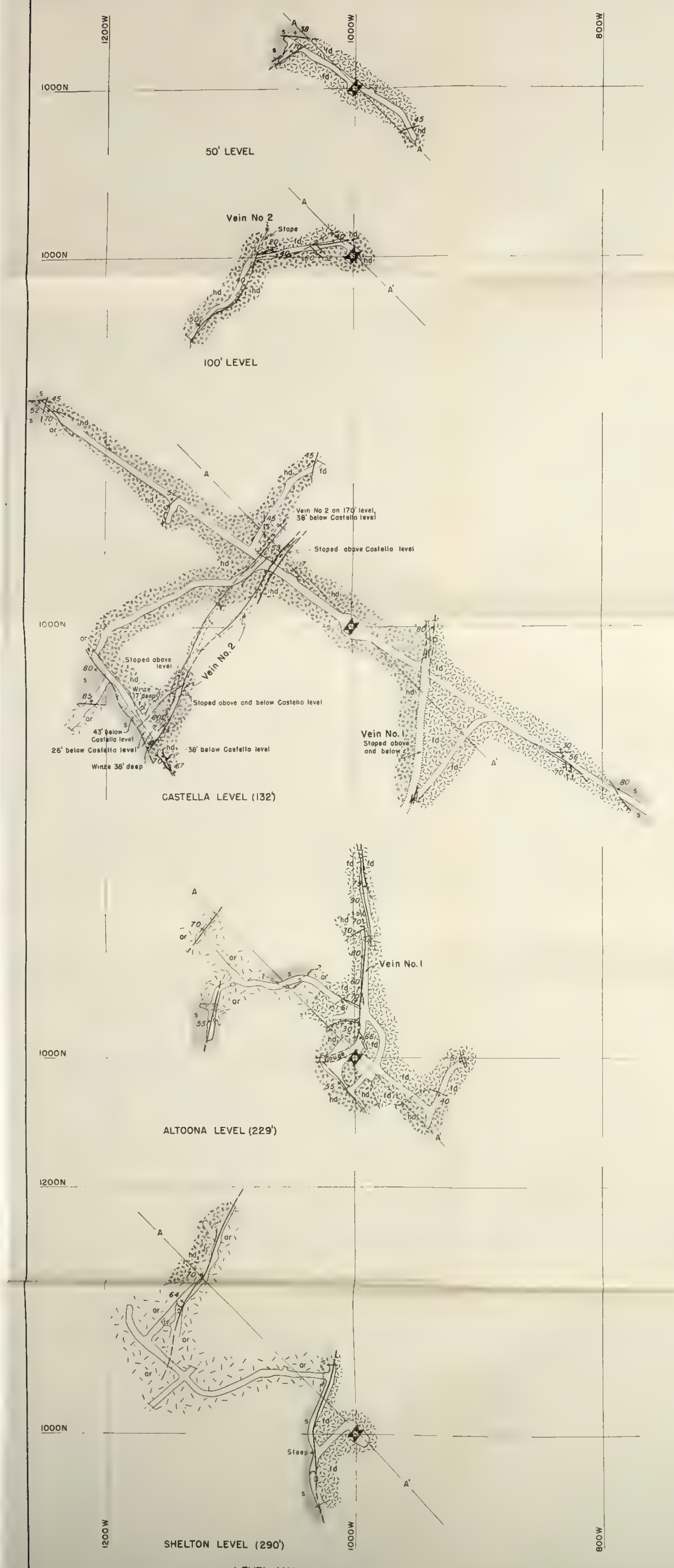
▨
Head of raise or winze

Ore chute

Caved down area

Caved workings

▨
Inaccessible area
(Compiled from early company maps)


1200W
1000W
800W
1000N
1200N
A
A'
hd
fd
ar
s
Vein No 2
Stope
Vein No 2 on 170' level, 38' below Castella level
Stoped above Castella level
Stoped above level
Winze 17' deep
Vein No. 2
Stoped above and below Castella level
43' below Castella level
26' below Castella level
38' below Castella level
Winze 38' deep
Vein No. 1
Stoped above and below
Vein No. 1
Gouge
Stope

50' LEVEL

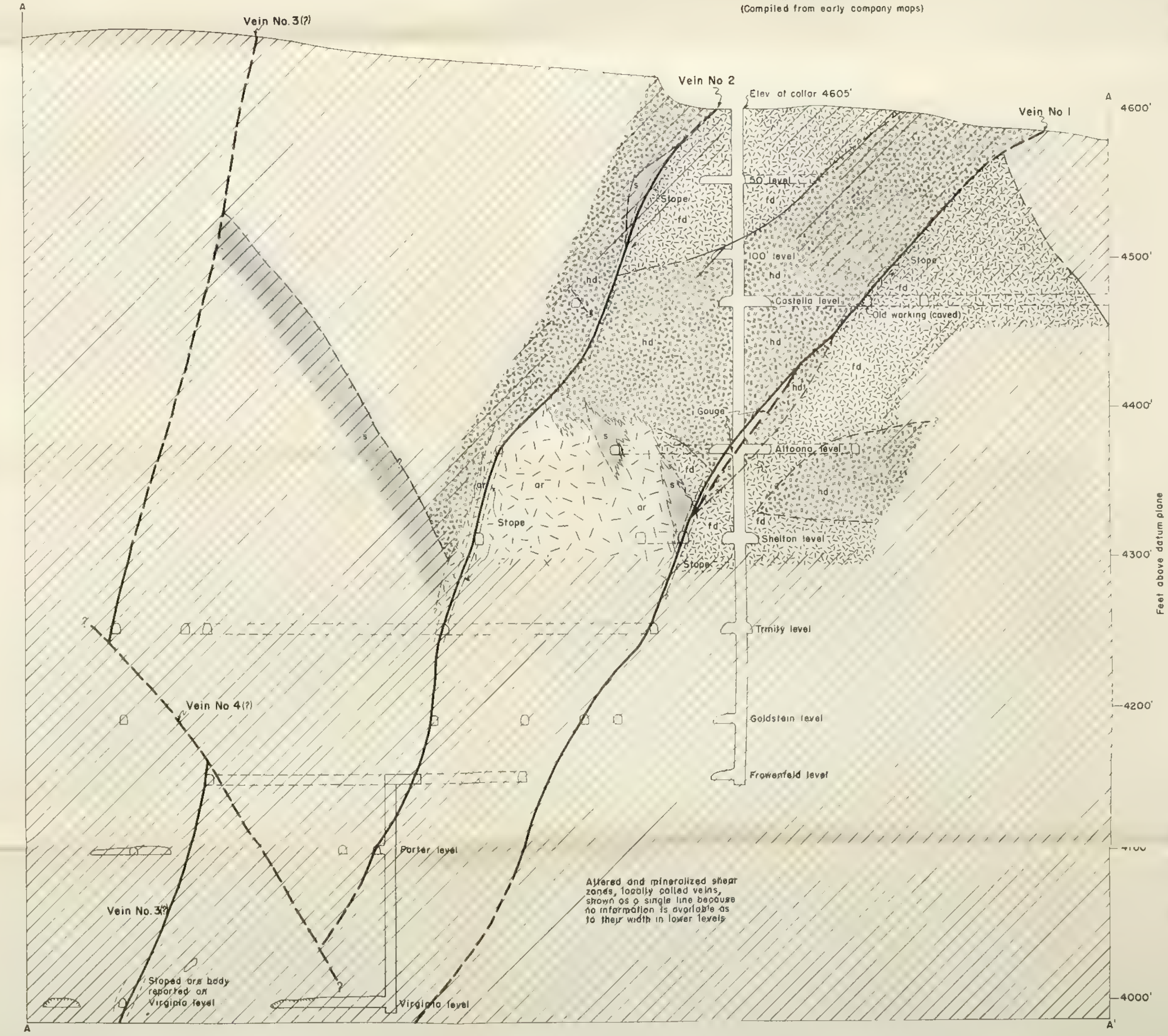
100' LEVEL

CASTELLA LEVEL (132')

ALTOONA LEVEL (229')

SHELTON LEVEL (290')

LEVEL MAPS OF ACCESSIBLE AREAS


A
A'
Vein No. 3(?)
Vein No 2
Elev of collar 4605'
Vein No 1
4600'
4500'
4400'
4300'
4200'
4100'
4000'
Feet above datum plane
50 level
100 level
Castella level
Old working (caved)
Altoona level
Shelton level
Trinity level
Goldstein level
Frowenfeld level
Porter level
Virginia level
Stope
Gouge
hd
fd
ar
s
Vein No 4(?)
Vein No. 3(?)
Stoped ore body reported on Virginia level

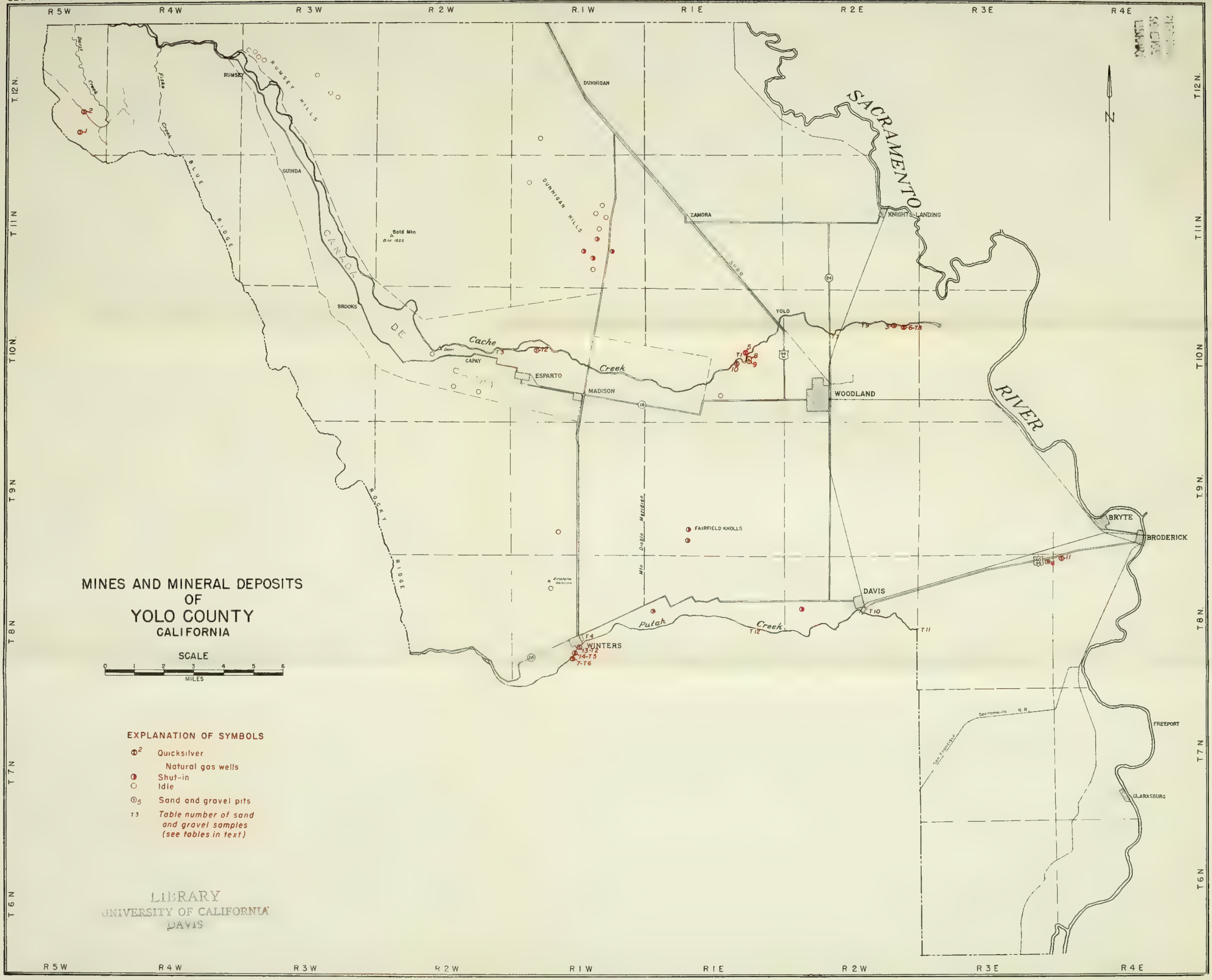
Altered and mineralized shear zones, locally called veins, shown as a single line because no information is available as to their width in lower levels

GEOLOGIC CROSS SECTION ALONG A-A'

Geology by: C Melvin Swinney, 1944

POCKET #3

A1


R 5 W
R 4 W
R 3 W
R 2 W
R 1 W
R 1 E
R 2 E
R 3 E
R 4 E
T 12 N.
T 11 N
T 10 N
T 9 N
T 8 N
T 7 N
T 6 N
N
Davis Creek
Fiske Creek
RUMSEY
RUMSEY HILLS
BLUE RIDGE
GUINDA
Bald Mtn
BM 1822
CAÑADA DE CAPAY
BROOKS
CAPAY
Dam
Cache Creek
ESPARTO
MADISON
DUNNIGAN
DUNNIGAN HILLS
ZAMORA
SACRAMENTO
KNIGHTS LANDING
YOLO
WOODLAND
RIVER
ROCKY RIDGE
Mt. Diablo Meridian
FAIRFIELD KNOLLS
Airplane beacon
WINTERS
Putah Creek
DAVIS
BRYTE
BRODERICK
FREEPORT
CLARKSBURG
Sacramento R.R.
San Francisco
T1
T3
T4
T9
T10
T11
T12
13-T2
14-T5
7-T6
6-T8
12
11
10
9
8
5
4
3
2
1

MINES AND MINERAL DEPOSITS
OF
YOLO COUNTY
CALIFORNIA

SCALE
0 1 2 3 4 5 6
MILES

EXPLANATION OF SYMBOLS

⊕2 Quicksilver

Natural gas wells

◐ Shut-in

○ Idle

⑤5 Sand and gravel pits

T3 *Table number of sand and gravel samples (see tables in text)*

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Quicksilver Deposits of the Cachuma District, Santa Barbara County, California 509

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO

STATE OF CALIFORNIA
EARL WARREN, Governor

DEPARTMENT OF NATURAL RESOURCES
WARREN T. HANNUM, Director

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO 11
OLAF P. JENKINS, Chief

Vol. 46 OCTOBER 1950 No. 4

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EARL WARREN, Governor
DEPARTMENT OF NATURAL RESOURCES
WARREN T. HANNUM, Director

DIVISION OF MINES
OLAF P. JENKINS, Chief

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Third Floor, Ferry Building, San Francisco 11

District Offices
State Building, 217 West First Street, Los Angeles 12
631 J Street, Sacramento 14
Department of Natural Resources Building
Cypress and Lanning, Redding

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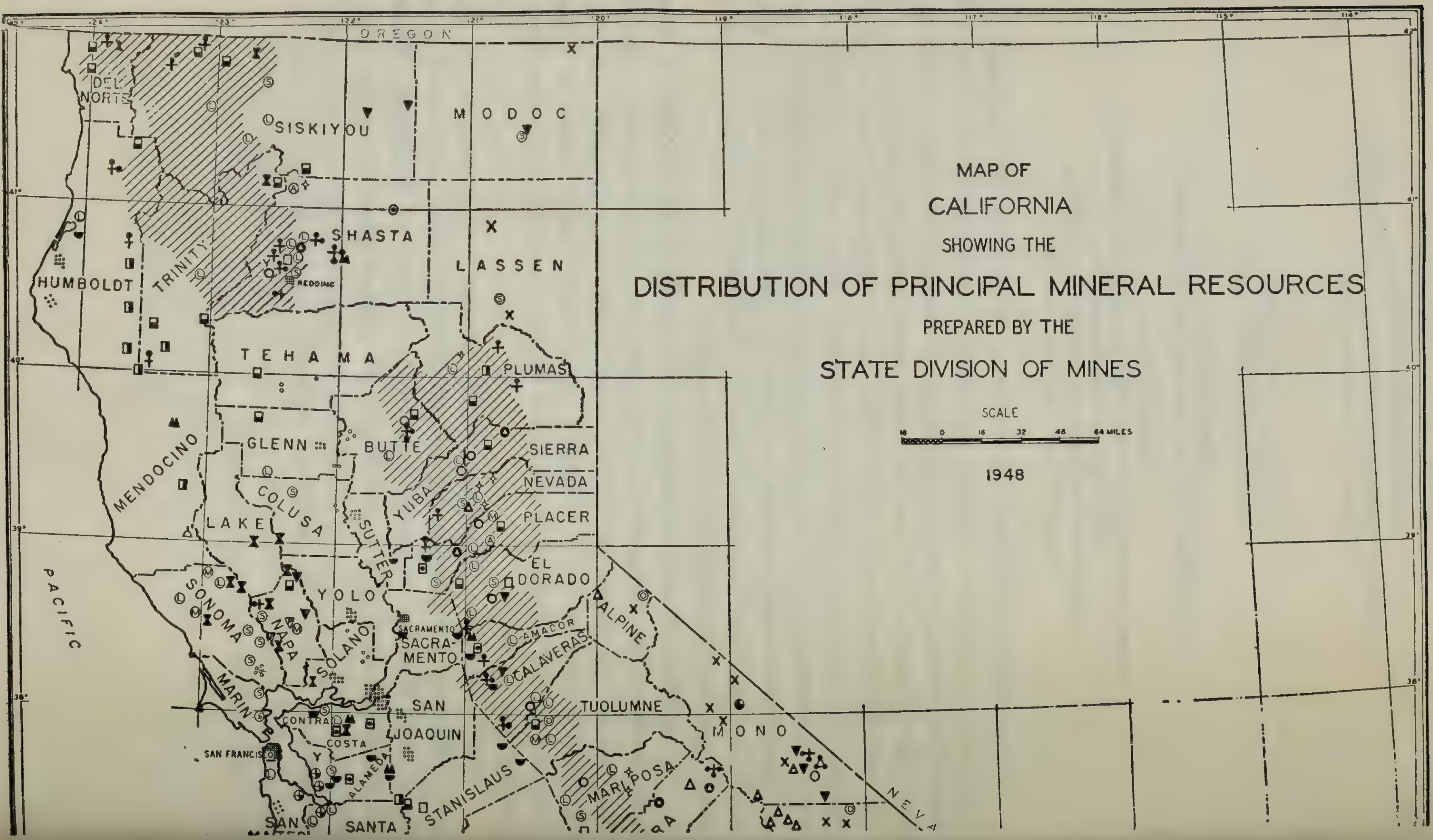
In addition to oral conferences in the offices of the Division of Mines, information concerning the mineral resources, mineral industry, geology, and mining operations of California is distributed to the public by means of publications, monthly releases, and letters. Each letter of inquiry received by the Division is answered by the technical staff member best qualified to do so.

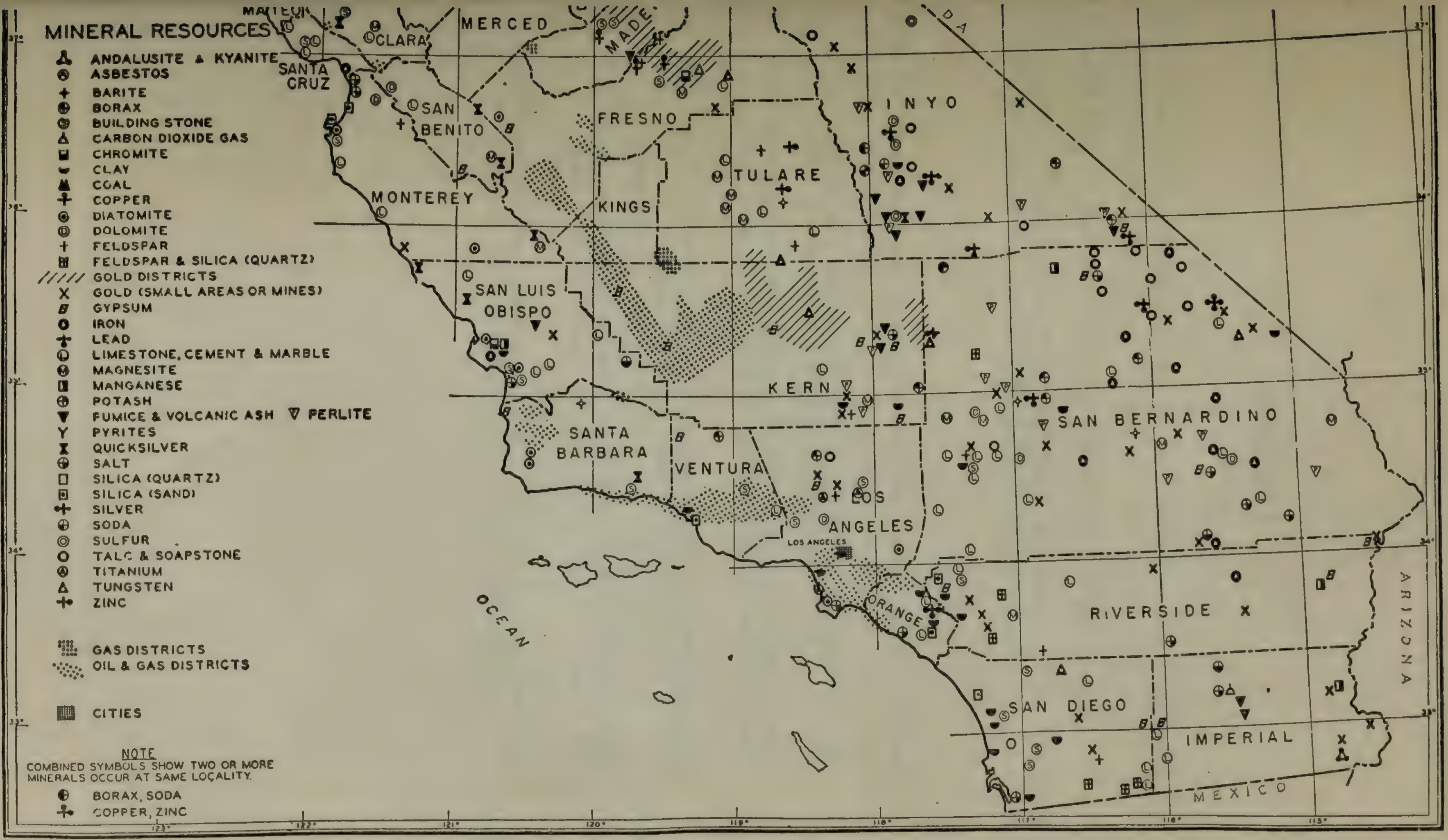
The principal publications of the Division of Mines are the quarterly **California Journal of Mines and Geology**, issued in January, April, July, and October of each year, and a series of **Bulletins. Mineral Information Service** is a monthly news release concerning the mineral resources and industry of California, designed to inform the public of discoveries, operations, markets, statistics, and new publications. It is distributed without cost upon request. A list of available publications will also be sent free upon request.



MAP OF
CALIFORNIA
SHOWING THE
DISTRIBUTION OF PRINCIPAL MINERAL RESOURCES
PREPARED BY THE
STATE DIVISION OF MINES

1948

SCALE
16 0 16 32 48 64 MILES
OREGON
PACIFIC
NEVA
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
REDDING
LASSEN
TEHAMA
PLUMAS
GLENN
BUTTE
SIERRA
NEVADA
PLACER
MENDOCINO
COLUSA
YUBA
SUTTER
LAKE
YOLO
EL DORADO
ALPINE
SONOMA
NAPA
SOLANO
SACRAMENTO
AMADOR
CALAVERAS
MARIN
TUOLUMNE
MONO
SAN FRANCISCO
CONTRA COSTA
SAN JOAQUIN
ALAMEDA
STANISLAUS
MARIPOSA
SAN
SANTA
124° 123° 122° 121° 120° 119° 118° 117° 116° 115° 114°
42° 41° 40° 39° 38°


MINERAL RESOURCES
ANDALUSITE & KYANITE
ASBESTOS
BARITE
BORAX
BUILDING STONE
CARBON DIOXIDE GAS
CHROMITE
CLAY
COAL
COPPER
DIATOMITE
DOLOMITE
FELDSPAR
FELDSPAR & SILICA (QUARTZ)
GOLD DISTRICTS
GOLD (SMALL AREAS OR MINES)
GYPSUM
IRON
LEAD
LIMESTONE, CEMENT & MARBLE
MAGNESITE
MANGANESE
POTASH
PUMICE & VOLCANIC ASH
PERLITE
PYRITES
QUICKSILVER
SALT
SILICA (QUARTZ)
SILICA (SAND)
SILVER
SODA
SULFUR
TALC & SOAPSTONE
TITANIUM
TUNGSTEN
ZINC
GAS DISTRICTS
OIL & GAS DISTRICTS
CITIES
NOTE
COMBINED SYMBOLS SHOW TWO OR MORE MINERALS OCCUR AT SAME LOCALITY.
BORAX, SODA
COPPER, ZINC
MATEO
CLARA
SANTA CRUZ
MERCED
MADERA
SAN BENITO
FRESNO
MONTEREY
KINGS
TULARE
INYO
SAN LUIS OBISPO
KERN
SANTA BARBARA
VENTURA
LOS ANGELES
SAN BERNARDINO
ORANGE
RIVERSIDE
SAN DIEGO
IMPERIAL
ARIZONA
MEXICO
OCEAN
DA
37°
36°
35°
34°
33°
123°
122°
121°
120°
119°
118°
117°
116°
115°

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MINES AND MINERAL RESOURCES OF MADERA COUNTY, CALIFORNIA

BY C. A. LOGAN *

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ABSTRACT

Madera County was created from a part of Fresno County in 1893. It extends northeastward from the center of San Joaquin Valley to the summit of the Sierra Nevada. Lumbering in the mountains was first of primary importance, but in later years it was superseded by diversified farming, especially cotton and grapes. Two main-line railroads traverse the valley section, and several state highways serve the western half of the county, but the higher mountains have few roads. The deficiency of rainfall in the valley is being supplemented by a supply of water from Millerton Lake, impounded behind Friant Dam on San Joaquin River, on the southerly county line.

Gold quartz mines produced substantial sums in the Coarse Gold, Grub Gulch, and nearby districts before the county was created. The only active gold production at present is carried on by a number of suction dredges working on Fresno, Chowchilla, and San Joaquin Rivers, granite at Knowles, near Raymond, has been the most important mineral product. Natural gas has been found in the valley only during the past few years. Pumice and pumicite are being utilized for several purposes. Copper ores were first mined in the 1860's, and small producers still make occasional shipments. Scheelite prospects are numerous but only one mine has been producing this ore commercially the past two years. Some prospecting of lead-silver-zinc ores has been done near Raymond Mountain and in the Minarets district. Both these districts have undeveloped iron deposits also.

The metamorphic rocks of the eastern foothills contain undeveloped prospects of other minerals such as asbestos, marble, and magnesite.

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* District Mining Engineer, Sacramento District, California State Division of Mines. Manuscript submitted for publication March 31, 1950.

INTRODUCTION

Geography

Madera County, with its valley section at the geographic center of the state, was created in 1893. The name means lumber in Spanish, and was aptly applied. In later years, diversified agriculture, especially the raising of cotton and grapes, became paramount in the western third, or valley region. Cattle raising is most important in the foothills and lower mountains. Timber is still abundant at higher elevations. The county extends northeastward from the center of San Joaquin Valley to the summit of the Sierra Nevada. It was previously the part of Fresno County north and east of the San Joaquin River, and south of Merced and Mariposa Counties.

The Santa Fe and Southern Pacific Railroads cross the valley region, and the western half of the county is well supplied with roads, including one to Yosemite National Park, part of which is in the county. The rest of the higher mountain region has few roads.

In the valley and lower foothills, precipitation is light, and all in the form of rain. Over a period of 23 years, the annual rainfall at Storey, near Madera, the county seat, ranged from 4.03 to 18.02 inches with a mean of 9.86 inches. Friant Dam, recently built on San Joaquin River, is the fourth largest concrete dam in existence and conserves water for agricultural use. Fresno River, flowing westward through the center of the county, and smaller streams carry little water in their lower courses during the dry season.

Geologic Features

The southwestern third of Madera County is a nearly flat alluvial plain sloping westward and merging on the east with the lower foothills, where a 1- to 3-mile wide band of marine sediments, tentatively mapped as upper Eocene, trends northwestward. From the north, Upper Jurassic metasedimentary rocks extend about 12 miles into the county along the east side of the Eocene.

Southward along the western slope of the Sierra Nevada, erosion has been more active than to the north, and has exposed more of the area of the granitic batholith. Granitic rock is in contact with the Eocene beds mentioned above, and also with the Mariposa rocks on the east. From there to the summit of the Sierra Nevada, granitic rocks, mapped as Jurassic acid intrusives, are principally in evidence, but the presence of roof pendants and small enfolded areas of pre-Cretaceous metamorphics is shown by deposits of limestone and scheelite.

In the higher mountains near the eastern boundary of the county, is a large area of Jura-Trias altered volcanics and several small bodies of younger volcanic rocks, some as late as the Quaternary. A feature of particular interest there is the Devil's Post Pile National Monument where columnar jointing is well developed in Quaternary basalt. Older sediments and volcanics were folded and altered, and partly overlain by these later volcanic rocks. The geology of the region, known as the Minarets district, has been described in detail in reports by the Division of Mines.[1]

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[1] Erwin, H. D., Geology and mineral resources of northeastern Madera County, California: California Div. Mines Rept. 30, pp. 7-78, pl. 1, 41 illus., 1934.

Trask, Parker D., and Simons, Frank S., Minarets magnetite deposits of Iron Mountain, Madera County, California: California Div. Mines Bull. 129, pp. 117-128, pl. 13, figs. 39-43, 1948.

Important contributions to the knowledge of underground geology of the valley section of the county have been made since 1934 from drilling records of companies searching for oil and gas. In the Chowchilla gas area, the discovery well drilled in 1934 by Pure Oil Company penetrated a thickness of 8,394 feet of sediments before entering the quartz diorite of the bedrock complex. This well passed through 1,000 feet of Recent and Pleistocene alluvium and 1,175 feet of undifferentiated non-marine Pliocene beds before striking the upper Miocene (Santa Margarita) marine beds. From there downward the age of the beds extended to Upper Cretaceous.[2]

In 1943, The Texas Company brought in the Gill Ranch gas field 16 miles southwest of Madera with a discovery well 9,154 feet deep, also bottomed in the bedrock complex. More wells were drilled there and 7 miles northeast of Firebaugh.[3]

MINERAL RESOURCES

Madera County was not established until 1893; prior to that year Fresno County was credited with the mineral production of the area. This early output was principally of gold, silver, and copper.

In the valley section, one of the county's more valuable mineral resources has been found and partly utilized only in the past 14 years. The Chowchilla natural gas area, 12 miles southwest of Chowchilla, contains dry natural gas of low calorific value. The Gill Ranch gas field, about 16 miles southwest of Madera, discovered in 1943, is now in production. Gas was also found 7 miles northeast of Firebaugh, on the Moffatt Ranch.

Pumice and volcanic ash in small areas north and west of Friant, have been utilized only in recent years. They have been transported by water to their present positions. They are now important items of mineral production.

Copper was mined as early as the 1860's in the vicinity of Daulton, on the foothill copper belt in the Upper Jurassic amphibolite schist, and both north and south of Daulton, from the Mariposa County line to Fresno River. Copper prospects have also been noted in the higher mountains, in the Minarets and Mt. Raymond districts.

Granite was produced in large quantities for over 40 years from quarries at Raymond. The total value of the output, probably about $10,000,000, was greater than any other mineral product from the county. The stone is noted for its fine quality, light color, and workability.

Gold quartz ore was found at or near contacts of the granite and pre-Cretaceous slate and schist which extend across the county through Grub Gulch to Hildreth on the south. The little gold mining done in recent years has been principally placer mining with small suction dredges along Fresno, Chowchilla, and San Joaquin Rivers.

Silver, lead, and zinc ores occur in Mt. Raymond district, where the Star mine (now included in the Smith-Bradford group) was worked in a small way in 1888-90. In the Minarets district, gold, silver, zinc,

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[2] Hodges, F. C., Chowchilla gas area: California Div. Oil and Gas, Ann. Rept. 29, no. 2, pp. 7-11, 1943.

[3] Kaplow, E. J., Madera County: California Div. Oil and Gas, Ann. Rept. 29, no. 2, p. 68, 1943.

Mineral Production of Madera County, 1893[1]-1948

Year	Gold, value	Silver, value	Copper		Brick		Granite		Miscellaneous stone[2], value	Miscellaneous and unapportioned		
			Pounds	Value	M	Value	Cubic feet	Value		Amount	Value	Substance
1893	[1] $150,696	$314										
1894	107,791	180					48,858	$31,494				
1895	162,323						39,590	49,662				
1896	104,339	1,240					48,628	73,525	$7,800			
1897	85,963						39,030	37,215	1,249			
1898	94,884	50			400	$2,800	23,103	49,673	500			
1899	73,758	292			439	3,070	47,433	36,000	2,500			
1900	104,134	3,833	500,000	$77,500	500	3,000	124,015	80,000			$65,000	Unapportioned, 1900-1909.
1901	82,749	2,600	108,430	17,077	500	3,000	96,716	294,799	600			
1902	35,128	3	18,600	2,139	230	1,840	105,845	78,041	4,000			
1903	93,070	3	36,000	4,680	216	972	128,581	389,800	1,000			
1904	75,303	25	10,300	1,313	750	3,750	113,627	98,083	500			
1905	50,867	10,014					42,316	123,106				
1906	22,390	508					65,472	176,416				
1907	13,303	506	1,895	379	1,250	12,500	99,278	93,372				
1908	45,107	1,264	113,293	15,454	250	2,250	140,086	123,668	2,140	2,279 lbs.	84	Lead.
1909	14,716	403	5,000	635			142,622	111,380	5,836			
1910	10,076	850	336,667	42,876	740	3,700	99,192	74,152	1,112			
1911	1,958	77	14,608	1,826	270	1,350	99,900	74,190	800			
1912	9,162	1,162	248,129	40,941	300	1,500	82,135	56,058	3,213	5,533 lbs.	249	Lead.
1913	14,489	1,617	532,403	82,522	315	1,650	150,994	270,123	1,466			
1914	4,506	36	35,359	4,703				186,543	6,221	50 tons	1,000	Pumice.
1915	11,214	2,126	40,294	7,051	200	1,400		84,632	37,640		1,000	Other minerals.
1916	10,306	1,772	124,286	30,574			128,865	172,191	7,915			
1917	18,914	489	372,123	101,590				114,400	1,525	221 lbs.	19	Lead.
1918	7,583	4,206	245,519	60,643				40,355	1,540			
1919	17,705	1,700	175,405	32,625				64,358	1,500			
1920	6,382	1,488	89,846	16,532				98,523				
1921	1,053	27						461,822	4,765			
1922	1,594	3,500						454,222	16,948			
1923	12,074	541						486,670			18,750	Other minerals.
1924	3,208	176	34,467	4,515				935,820	11,750			
1925	2,366	82						1,358,410	16,600			
1926	1,708	22						418,683	5,325			
1927	4,181	38						(3)	(3)		1,055,447	Granite paving blocks and miscellaneous stone.
1928	3,580	144	14,171	2,031			(3)		(3)		508,740	Granite and miscellaneous stone.
1929	1,474	475	19,254	3,389			(3)		(3)		1,022,072	Granite and miscellaneous stone.
1930	1,062	70	98	13			(3)		(3)	4,933 lbs.	250 674,387	Lead. Granite and miscellaneous stone.
1931	2,405	11					(3)		2,015		483,912	Other minerals.

1932	9,230	52	----------	----------	----------	----------	(3)	----------	(3)	----------	288,739	Granite and miscellaneous stone.
1933	8,962	712	496	32	----------	----------	(3)	----------	(3)	5,442 lbs.	210	Lead.
										----------	123,198	Granite, miscellaneous stone, volcanic ash.
1934	13,165	69	----------	----------	----------	----------	(3)	----------	53,590	----------	197,320	Granite and volcanic ash.
1935	21,410	83	----------	----------	----------	----------	(3)	----------	54,871	----------	230,280	Granite, lead, volcanic ash.
1936	23,485	180	----------	----------	----------	----------	(3)	----------	44,020	----------	154,907	Granite, volcanic ash.
1937	13,615	110	2,007	243	----------	----------	(3)	----------	70,502	----------	48,695	Granite, pumice, volcanic ash.
1938	9,485	56	----------	----------	----------	----------	----------	----------	2,875	----------	17,500	Other minerals.
1939	30,135	181	----------	----------	----------	----------	(3)	----------	(3)	----------	89,515	Granite, miscellaneous stone, volcanic ash.
1940	49,000	340	----------	----------	----------	----------	(3)	----------	22,549	2,860 lbs.	143	Lead.
										----------	38,042	Granite, pumice, volcanic ash.
1941	52,395	335	----------	----------	----------	----------	(3)	----------	----------	----------	127,600	Granite, pumice, miscellaneous stone, volcanic ash, tungsten.
1942	25,095	172	64,988	7,864	----------	----------	(3)	----------	(3)	----------	54,596	Granite, volcanic ash, miscellaneous stone.
1943	350	91	21,940	2,852	----------	----------	(3)	----------	(3)	----------	52,282	Natural gas, volcanic ash, miscellaneous stone, tungsten.
1944	700	128	72,221	9,750	----------	----------	----------	----------	(3)	----------	63,563	Mineral paint, natural gas, pumice and volcanic ash, miscellaneous stone, tungsten.
1945	35	59	22,957	3,099	----------	----------	----------	----------	(3)	----------	186,693	Natural gas, pumice and volcanic ash, miscellaneous stone.
1946	1,925	15	----------	----------	----------	----------	----------	----------	----------	33,052 tons	186,233	Pumice and volcanic ash.
										----------	203,190	Feldspar, natural gas, miscellaneous stone.
1947	6,895	52	----------	----------	----------	----------	----------	----------	----------	----------	230,125	Natural gas, pumice, stone, and tungsten concentrates.
1948	(3)	(3)	10,000	2,170	----------	----------	----------	----------	----------	8,311 tons	82,719	Pumice and pumicite.
										26,399 tons	19,040	Sand and gravel.
										58 tons	----------	Tungsten concentrates.
										----------	342,698	Natural gas, gold, silver, tungsten concentrates.
Totals	$1,720,403	$44,479	3,270,756	$576,973	6,360	$42,782	----------	$7,107,386[3]	$394,867[3]	----------	$6,598,514	

GRAND TOTAL VALUE—$16,584,404

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[1] Madera County created March 11, 1893, from a portion of Fresno County. Between 80 and 90 percent of the gold and silver produced in Fresno County prior to 1893 was from that part now in Madera County.

[2] Includes crushed rock, rubble, riprap, sand, gravel.

[3] See under "Unapportioned."

and copper have been found and considerable work has been done. Both localities are in the high mountains.

Iron deposits are found in the Minarets and Mt. Raymond districts. These deposits remain undeveloped, although the Minarets deposit was drilled by the U. S. Bureau of Mines during the last war.

Tungsten ore was produced from several deposits between 1940 and 1946, and work was done on many more. All contained scheelite except one in which hübnerite was found. The deposits occur in the mountains where granite has been in contact with limestone. The Strawberry mine near Jackass Meadows has been the leading producer. After two years idleness, work was recently resumed there.

Prospects of other minerals not known to have made commercial production include asbestos, magnesite, marble, molybdenite, cobalt, nickel, silica, and soapstone.

Common brick was made years ago in a plant at Madera. Sand and gravel are produced for local use and a commercial sand plant was operated in the 1920's on Cottonwood Creek 5 miles southeast of Madera.

Asbestos

An amphibole asbestos district, southeast of Grub Gulch, was visited in October 1948. Indications of asbestos were seen between Grub Gulch and Fresno River along the old Wawona wagon road. The only place where any work was noted was on the Deep Canyon claim, 1 mile east of Grub Gulch. Here a shallow pit 20 feet square exposed a 4-foot width of amphibole asbestos, part of which is of fair quality. Nothing has been done here in recent years. The asbestos in this region occurs along a fault striking N. 80° W.

Deep Canyon claim is in sec. 14, T. 7 S., R. 20 E., M. D., on the west side of Fresno River at an elevation of 1,750 feet. At the time of visit it was claimed by Mrs. Nellie Alexander, Ahwahnee.

Other prospects of amphibole asbestos at the Savannah mine in section 14 and at the Baker mine in section 24 in the same township are along the southeastward trend of the same structure in which the Deep Canyon claim is found. These are both old gold quartz mines that have been idle in recent years. So far as could be learned, no work has been done on the asbestos from either of these mines.

Copper

The copper mines of the foothill copper belt in this county, which in early days was a part of Mariposa County and later a part of Fresno County, shared in the copper mining activity of Civil War years. The Buchanan mine had a small smelter and shipped 60 percent copper matte to San Francisco in 1865, which sold at 16 cents a pound, but the same grade would not bring 9 cents a pound when 100 tons was sent there in 1867. A second period of copper production began in 1899 with the building of a smelter at Madera to treat ore from deposits on the Daulton Ranch. The smelter operated 4 months, and about 500,000 pounds of copper was produced in 1900, but output dropped to only 10,300 pounds in 1904. From 1908 to 1920 some copper was mined and sold each year; the total production for this period was 2,234,827 pounds. Since then, work has been limited and sales of copper small and irregular. None of the mine developments exceeds a few hundred feet in depth.

Most of the production has come from a few properties in Tps. 8, 9, and 10 S.; Rs. 18 and 19 E., where the southern end of the Mariposa (Jurassic) marine metasediments are in contact with granodiorite on the east.

The following notes cover items not previously given in earlier reports.[4]

At Bach Ranch, 1 mile west of the Buchanan mine, copper prospects were worked superficially during the first World War. R. Bach shipped a few tons of ore carrying 13 percent copper and 70 ounces of silver a ton. About 1926 a shaft was sunk 70 feet and a drift was run from the bottom, 100 feet. High assays in copper and silver, with some gold were reported, but evidently the amount of ore found did not encourage mining. The property was later sold by Bach.

Daulton Copper mine (Ne Plus Ultra, California Copper Co.) is in the E½ sec. 35, T. 9 S., R. 18 E., M.D., 1 mile by road southeast of Daulton on the Berenda branch of the Southern Pacific Railroad. It contains 60 acres, patented, and is owned by Mrs. A. M. Bradford, P. O. Box 207, Madera.

The mine is at an elevation of 450 feet on a nearly north-striking ridge, which is about 2,000 feet long and 50 feet above the valley. This ridge is formed of mica schist derived from Mariposa clay slate. The extent of the original prospects is indicated by the 1,000 feet of the surface which is riddled by shallow pits and numerous shafts.

Since the 1860's work has been done at intervals on this land by several operators who have left no detailed record of technical value. The mine was sold in 1899 for $125,000 to California Copper Company which worked for a few months in three shafts and built a smelter at Madera for treating the ore. The venture was unsuccessful, and work stopped in June 1900. The mine has been worked irregularly since. In recent years production has been in the form of ''cement'' copper. From 1942 to 1944 inclusive, West Lode Reduction Company pumped water from the old mine working and precipitated copper on scrap iron. In 1945 Ace Alexander produced some copper by the same method. During these years the mine was the principal copper producer of the county. No further work had been done up to the time of visit in April 1949, when the underground openings were inaccessible. The mica schist in which the ore occurs is notable for the large amount of andalusite present in the form of coarse chiastolite crystals. Many of these are 2 inches or more in length and up to ½ inch in diameter. The outcrop of the schist strikes nearly due north for 1,000 feet from the north shaft; at the shaft the strike is about N. 10° W.; possibly this indicates a small fault. The dip of schistosity is 70° E. The ore-bearing zone is about 100 feet wide. According to Storms,[5] who visited the mine in 1900 when it was being worked:

> "there are several shoots of ore having an approximate parallelism with many ramifying branches. There are also dikes cutting the formation.

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[4] California Div. Mines, The copper resources of California: California Div. Mines Bull. 23, 282 pp., 1902.

Hausmann, A., The copper resources of California: California Div. Mines Bull. 50, 366 pp., 1908.

Laizure, C. McK, Madera County: California Div. Mines Rept. 24, pp. 321-323, 1928.

Cox, Manning W., and Wyant, Donald G., The Jesse Belle copper mine, Madera County, California: California Div. Mines Bull. 144, pp. 151-157, 1948.

[5] Storms, W. H., The Mother Lode region of California: California Min. Bur. Bull. 18, pp. 149-150, 1900.

> The ore normally is an iron-copper sulphide, but in the zone of semi-oxidation, between the thoroughly oxidized gossan ores and the normal sulphide ores, oxidation is taking place very rapidly. This oxidation results in giving out a large amount of heat, which occasions the mine workings to be unusually hot. The ore taken from certain shoots in this mine, when delivered on the dump, frequently takes fire within a few days by spontaneous combustion, and on several occasions has set on fire the cars in which the ore is transported to the smelter at Madera."

At that time, the deepest of 3 shafts was 145 feet. Now the north shaft, double compartment, is 100 feet deep. It did not strike the main vein and according to Bradford is in low-grade rock. The Bradford north shaft is 135 feet deep. On its 85-foot level a drift was run south 75 feet, where the old winzes and stopes extend downward to the 200-foot level of the old shaft. This level extended 400 feet southward, where it connected with a raise of 100 feet to the 100-foot level of the old shaft. From the 200-foot level also there is a south drift believed to be 200 feet long, which was run in 1906 and has not been entered since. The south shaft, from which water has been pumped in late years to recover ''cement'' copper, is 230 feet deep on 70° incline and is open to 100 feet. No details are available about the original Daulton or China shaft.

In the Bradford north shaft the ore in the drift at the 85-foot level was reported to carry 3.75 percent copper and 7 percent zinc,[6] but according to L. M. Bradford it averages 6 percent copper and 10 percent zinc. He states this ore is still 10 feet wide at the bottom of the shaft. He believes the main ore shoot is possibly 150 feet long, extending from this shaft southward, the southern half having been partly worked.

Water from the south shaft was pumped through 750 feet of 8-inch wood pipe to 20 V-shaped vats 4 feet deep by 6 feet wide at the top by 15 feet long. After precipitation of the copper on scrap iron, the water was allowed to percolate down through the dump and into the mine workings. The last activity was in 1947.

Jesse Belle copper mine is in SE¼ sec. 13, T. 9 S., R. 18 E., M.D., and secs. 18 and 19, T. 9 S., R. 19 E., M. D. It has been described in great detail by Cox and Wyant.[7] More work has been done in late years on this mine than on any other copper prospect in the county, but the total recorded production since 1919 has amounted only to 38,736 pounds of copper, 89.92 ounces gold, and a small amount of silver.

Copper occurs in chalcopyrite associated with some pyrite and pyrrhotite. Cobaltite was found to form 0.59 percent of one lot of 40 tons of sorted ore from the 200-foot level. This ore carried 4.12 percent copper, which is probably a higher than average percent for the mine. Cox and Wyant give a weighted average of 0.14 ounce gold and 0.59 ounce silver. The principal shaft is 300 feet deep. On the 300 foot level, one drift was run 125 feet about N. 20° W. and another 125 feet S. 15° E. On the 100-foot level, a crooked drift was run 270 feet west of north. An ore shoot 40 feet long by 3.8 feet thick, averaging 4.3 percent copper in the south drift of the 300-foot level and one 80 feet long by 3.8 feet thick averaging 3.2 percent copper in the north drift on the same level, were inferred from assays left by former operators. The latter shoot was stoped above the 100-foot and 200-foot levels. One or two men have been employed irregularly lately.

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[6] Laizure, C. McK, Madera County: California Div. Mines and Mining Rept. 24, pp. 317-345, 1928.

[7] Cox, Manning W., and Wyant, Donald G., The Jesse Belle copper mine, Madera County, California: California Div. Mines Bull. 144, pp. 151-157, 1948.

Besides the above workings, some shallow pits and shafts have been sunk on the Rosati vein on the north, and on other veins on the west, north, and south. The owners of the land are the Daulton Estate and M. R. Buchenan, Madera.

Feldspar

Carol Jane claim is in secs. 15, 21 and 22, T. 7 S., R. 22 E., M.D., at Bass Lake. The owner is Myra Anderson, 1405 North Fresno Street, Fresno 4.

Small shipments of potash feldspar have been made during the past few years. It was taken out in the course of assessment work. This claim is on the south side of Bass Lake, about 7 miles by road east of Oakhurst.

Gold Placer Mines

In recent years placer mining has been done almost entirely with small suction dredges along the lower courses of Fresno, Chowchilla, and San Joaquin Rivers in Madera County. There is a very marked increase in this type of work at present (February 1950). The material handled is the smaller gravel from the beds and bars of the streams which can be worked by pumps from 2 to 10 inches in diameter. The centrifugal pump has long been used on suction dredges for river and harbor work, and in mining has been applied to the dredging of tin-bearing gravel on a much larger scale than ever attempted in gold mining. For the latter, the outfits are mostly small and light, requiring only one man on a shift. The capacity ranges from 2 or 3 cubic yards an hour with a 2-inch pump to 55 to 60 cubic yards with an 8-inch pump, depending on character of gravel, height of lift, speed at which the pump is run, and pump or nozzle design. The largest suction dredge made in California for gold mining is now being assembled at Madera.

Many mechanics familiar with centrifugal pumps have designed their own pumps and built small dredging outfits. In Madera and Fresno Counties the Becker pump, made at the Valley Foundry, Fresno, and the Ace pump, distributed by Pacific Mine & Mill Supply Company, Fresno, have been used by several small operators. In order to handle coarser gravel with a given size pump, some operators have designed pumps with increased clearance between the impellers and pump case. This results in increased slippage and reduced capacity but does permit a wider ranger of feed size. With an open suction nozzle, a pump ordinarily should not be expected to handle material measuring more than seven-tenths of the diameter of the pump intake. Elbows in the discharge line cause trouble with slabby pieces. On the better outfits, machinery is installed on barges made of steel pontoons, but on some of the less expensive ones the pump, engine and short shallow sluices are installed on small wooden barges floating on oil drums. If the pump is above the water level, a second small pump may be needed to prime the first.

Several improvements have been made and patented to increase effectiveness of the pump and facilitate moving the barge. These include ''digging'' nozzles which rotate through a full circle or oscillate through part of a circle. They are mounted vertically, and provided with mechanical means of lifting and lowering. Such dredges must be supplied with lines anchored on shore and drums for handling the lines when working across a stream. Power on the simpler outfits may be supplied by an automobile engine, but the larger pumps and more elaborate rigs require diesel or gasoline engines of 60 horsepower or more.

A. E. Bennett, Aukum, designed pumps which he used successfully for suction dredging on San Joaquin River up to 1941.

H. A. Berg, Madera, operated a small suction dredge on Fresno River in the Dennis district, in 1941, handling about 22,000 cubic yards of gravel which yielded 41 cents gold a cubic yard. In 1947, he operated with a 4-inch pump on the Blazer land in secs. 23 and 27, T. 9 S., R. 19 E., on Fresno River.

F. J. Gibbons and Son, Stockton, operated suction dredges on Fresno River 17 miles above Madera from 1941 to 1945. Gibbons designed his own pumps and built the 18- by 20-foot barge on which equipment was installed. Fifty 50-gallon oil barrels were used as pontoons for the barge. Starting with a 2-inch pump, he replaced this with 4-inch and 6-inch pumps successively. Working in 4 feet of water, a depth of 10 to 15 feet of gravel was handled at the rate of 35 cubic yards an hour with the 6-inch pump. Armored (wire-inserted) hose was used for suction, with a nozzle of 6-inch pipe 2½ feet long. The pump was run at 665 revolutions per minute. A tractor motor of 35 brake horsepower supplied power. Gibbons stated that pumps were designed with enough clearance to permit handling gravel nearly as large as the diameter of pump intake. Gold was saved in 14 feet of sluice 21½ inches wide set on a grade of 1 inch in 12 feet. The bottom of sluice was covered with canvas or burlap, with two layers of expanded metal, covered by ¼ by ⅜ inch heavy steel screen.

G. E. Noble and Sons operated a suction dredge on the J. T. Pierce Ranch in 1942, handling 7,790 cubic yards of gravel which yielded 118 ounces of gold and 35 ounces of silver.

On the Polk Ranch, 9,000 cubic yards of gravel dredged in 1942 yielded 148 ounces of gold and 32 ounces of silver. The figures of production from the last two operations were published in Minerals Yearbook of the U. S. Bureau of Mines.

At present (February 1950) more suction dredges are at work in Madera County and are being constructed for use there, than at any time in the past. Gravel is being dredged on Chowchilla River near Raymond, on San Joaquin River near Friant, on Fresno River above Adobe Ranch, and on Coarse Gold Creek. The total amount of gravel available in the region is small, and the gold content is said to be generally too small to attract other types of dredge operators. The suction dredge as used here requires only one man per shift and the cost of equipment is small, compared to that of a dragline.

Two of these dredges will be described in some detail. The first is a large new dredge with a 16-inch pump, now being assembled at Madera. The other is the Becker type, which has been used successfully for some years in that region.

Mr. H. E. Larsen, Route 4, Box 349, Madera, and Dr. W. G. Hughes, San Rafael, have leased land along Fresno River on the Adobe Ranch, 14 miles east of Madera and are assembling at Madera the equipment for a suction dredge believed to be larger than any used so far in California for gold dredging.

The hull will consist of steel pontoons, all of 3/16 inch steel except the deck, which is 12 gauge. Two main pontoons are each 8 feet wide by

44 feet long by 30 inches deep, and a middle pontoon is 6 by 26 feet by 30 inches. Two spaces 18 inches wide extend along the entire length of both sides of the center section to provide space for copper cooling tubes to be submerged in the water for cooling the Diesel engines. The center pontoon also provides room for storing 600 gallons of Diesel fuel oil.

Power will be furnished by two Marine Diesel engines of 225 horsepower each to operate the pump and a 77 horsepower Diesel engine for auxiliary power to handle winches, priming pump, furnish lights, etc. Hydraulic winches will give a rope speed of 90 feet a minute. A 1½-inch Vickers pump will furnish hydraulic power for raising and lowering the nozzle. The 16-inch pump is designed with 16 inches clearance between the runners and case. A hard-faced open suction nozzle will be used at the start, and Mr. Larsen believes it will be possible to handle boulders up to 14 inches in diameter. The gravel to be worked is as much as 35 feet deep, but the outfit is believed to have a depth capacity of 40 feet. A belt-conveyor stacker 40 feet long will be used for coarse tailings. Plans call for 500 square feet of riffles, about half to be steel-covered Hungarian and half expanded metal lath. All controls will be at a central point to permit operation by one man. Mr. Larsen estimates that the capacity will be about 200 cubic yards an hour, and that dredging will start in June. The total yardage to be worked is uncertain, but operation may extend for 1½ miles along the river.

Williams and Santoni dredge (inactive) was operated by Fred Williams, Clovis, and Fred Santoni, Route 13, Box 258, Fresno, on the Madera County side of San Joaquin River in sec. 7, T. 11 S., R. 21 E., near Friant. This is a Becker-type dredge, using a 6-inch Becker pump made at the Valley Foundry, Fresno, and a rotating digging point, also covered by a Becker patent. Equipment is carried on a steel barge 15 by 24 feet, consisting of 6- by 8-foot pontoons and 2 smaller pontoons.

Power is furnished by a 50-horsepower 4-cylinder Fageol gasoline engine. The pump is driven through a shaft with clutch from the front end of the engine, and from the rear a 15 kilowatt electric generator is driven to supply a 5-horsepower motor on the rotator, 3-horsepower motor on the trommel, 3-horsepower motor for the elevator and for the winch on shore lines, and to supply electric lights. The dredge was operated 24 hours a day with one man on each 8-hour shift.

The pump is operated at 450 revolutions per minute, and requires 12 to 15 horsepower. The vertically mounted suction column carries a rotating digging section 5 feet long, of 6-inch inside diameter steel pipe. The lower 14 inches is perforated with 14 holes 2 inches in diameter and is tapered down to a straight cutting edge 5 inches by ½ inch. The lower 14 inches is built up to a thickness of ¾ inch with Marcol 3. Rotation is provided by a worm drive and gears from a Fordson tractor, which, together with the difference in diameters of driving and driven pulleys, reduces speed from 1,800 revolutions per minute at the electric motor to 20 revolutions per minute at the digging bit. A similar train of gears is used with the 3 horsepower motor which operates the winch lines to the shore and raises and lowers the digging assembly.

The pump delivers its load to a trommel 10 feet long by 30 inches in diameter, rotating at 20 revolutions per minute and having a screen with 3/16-inch by ½-inch slots. This and the sluices for gold saving are carried on an upper deck. The four steel sluices each 20 feet long by 2½ feet wide carry a total of 130 square feet of riffles, half of which are Hungarian riffles covered with ⅛-inch by 1¼-inch mild steel, and half are diamond mesh screen over metal lath. The former are loaded with mercury. All gold is very fine, but saving is reported to be good. The capacity of the dredge is 30 to 40 cubic yards an hour.

The following are at present planning on operating suction dredges in the county. All are using pumps with open suction nozzles and the outfits have been designed and built locally. Generally only one man per shift is employed on each dredge.

On Chowchilla River, a short distance up-stream from Raymond, three outfits are working. Chowchilla Dredging Company has a dredge with a 10-inch pump on the Desmond land. Howell Brothers of Snelling are operating a dredge with a 12-inch pump. Snyder has a 10-inch outfit at work.

On Coarse Gold Creek, an eastern tributary of Fresno River joining it 19 miles northeast of Madera, Ernest Noble of Raymond, is operating a suction dredge with a 10-inch pump. Plans are being made to install 2 or 3 suction dredges on this stream.

On Fresno River, just up-stream from the Adobe Ranch, 14 miles northeast of Madera, R. Brock, Fresno, has a dredge with an 8-inch pump and Sherwood Green, Madera, has a dredge with a 10-inch pump.

On San Joaquin River, besides the Williams and Santoni dredge already described, is a 4-inch suction dredge between the Friant highway bridge and Friant Dam. This belongs to Lon Jones, Jamestown, and is only being worked experimentally.

Granite

The production of granite was an important business in Madera County for fifty years, from 1893 to 1942. The value of the annual output first exceeded that of gold in 1901, and from then until 1942 granite remained the leading mineral product of the county with a total gross value of about $10,000,000. The stone produced in the greatest quantity from the two principal quarries has been described as a biotite-muscovite granite. It is light gray in color, of medium fine grain, homogeneous and easily worked, and is free of dark patches or blotches. Variations have been noted in other quarries in the district, which is within a few miles east and southeast of Raymond. The largest production has been from the Knowles or Raymond quarry and the McClellan, later know as the McGilvray Raymond quarry. Both of these were opened before Madera County was created. Smaller and shorter-lived operations were carried on at several smaller quarries. No quarry was actually in operation at time of visit in 1949, although some work had been done recently at the Raymond quarry, and at a small stone-cutting plant near Knowles.

The interruption of large building projects caused by the last war, the competition of portland cement and ceramic products, the depression of the 1930's, and more recently, the higher wage scales and labor disputes have all had adverse effects on the granite business as well as on the sale of other natural building stones. The Madera County quarries were worked longer than others in northern California. Raymond granite was used in many large buildings, including several at the University of California at Berkeley, the San Francisco City Hall, the U. S. Custom House in San Francisco, the Los Angeles City Hall, and many others.

Kingsland Granite Company began work in 1934 on a quarry in sec. 16, T. 9 S., R. 20 E., M.D., north of Bates and 20 miles by road northeast of Madera. Large blocks of granite were taken out and hauled by truck to a cutting and finishing plant at Madera. A large lathe, 3 gang saws, carborundum machines, and surfacing machines were used to prepare granite for use in a large building project. The company continued production through 1936 under the same name. In May 1937, the corporation name was changed to Madera Quarries Company under which title granite was marketed from 1938 to 1942 for building and monumental use. No production was reported after 1942, and the company withdrew as a California corporation July 30, 1946.

McGilvray quarry [8] was one of the two principal granite producers of the county, having been in operation as the McClellan quarry when Madera County was created in 1893. At present, an area of 65.15 acres near Knowles in the E½ sec. 27, T. 8 S., R. 19 E., M. D., containing the quarry is assessed to Alexander B. McGilvray. Most of the equipment has been removed. It was operated independently until 1928 on a large scale. In that year it was merged with the nearby Knowles (Raymond) quarry and with other large granite quarries elsewhere in California, by McGilvray Raymond Corporation. That corporation continued production from the Raymond quarries through 1937. No work appeared to have been done recently when the site was visited in 1949, except for the utilization of some waste for crushed rock on roads. In 1914, this quarry employed from 250 to 300 men principally to quarry and finish stone for the San Francisco City Hall.

Raymond Granite Company's quarry, also known as the Knowles quarry, is on 74.93 acres in secs. 22 and 23, T. 8 S., R. 19 E., M. D., at Knowles, 2 miles east of Raymond. It is assessed to M. Davidson, c/o Dan McCarty, 6450 Camden Street, Oakland. George Briggs was local foreman in 1949. It is one of the two largest quarries of the county. It was worked for a longer period of time than any other, having been active since 1888. Much of the equipment used during the period of large-scale operation is still on the quarry and in the stone cutting shed. In 1914, 175 men were employed and granite was being supplied for many large buildings in California. In 1928 this quarry became part of a merger formed by McGilvray Raymond Corporation and was operated by that company to and including 1937. When visited in 1949, work had just stopped, but there was a prospect of a contract being obtained that would permit resumption. Two or three men were employed in the quarry and 7 in the stone cutting shed earlier in the year. The granite outcrop was in the form of a flat dome on a hillside, offering advantageous working conditions. The stone is extremely light gray, of medium grain and of very uniform composition. It is easy to work both in the quarry and in cutting or finishing, and can be obtained in blocks of any size likely to be desired. It has been used in many of the largest buildings in the state.

Just south of Knowles is a new stone working plant which was idle at time of visit. A stone-cutting shed 36 by 80 feet, covered with corrugated aluminum, houses an overhead electric crane for handling blocks of granite, and two stone cutting machines. Two small buildings house other machinery and equipment. There is a derrick for handling large blocks of stone. Some work had been done recently in the rough dressing of small slabs of granite from one of the quarries of the district, but the plant was deserted and ownership could not be ascertained.

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[8] McLaughlin, R. P., and Bradley, W. W., Madera County: California Min. Bur. Rept. 14, pp. 562-563, 1916.

Iron

Hart iron deposit is covered by two patented groups of placer claims called the Nevada Consolidated placer mine and the T. G. Hart claim, which include a total of 560 acres in secs. 14, 15, 22, and 23, T. 5 S., R. 22 E., M. D. The owners are Helen Hart Waisanen and Ruth Hart Rotherham, 330 Lexington Way, Burlingame.

The claims cover the peak of White Chief Mountain, elevation 8,658 feet, and extend northwestward from the center of section 23 to the northwest corner of section 15. The nearest road ends half a mile west of the latter in section 16. Magnetite and hematite have been prospected by pits and shallow shafts. Substantial amounts of ore are claimed here, but no recent work has been done. Friant is 42 miles away by railroad.

Minarets iron deposits, the largest in the county, have been repeatedly described. The following is the abstract of the latest report on this property; it was written by Parker D. Trask and Frank S. Simons: [9]

> "The Minarets magnetite deposits are located at an altitude of 10,000 feet near the crest of the Sierra Nevada, 14 miles by trail from the nearest road, and 90 miles from the nearest railroad at Friant, near Fresno, California. Most of the ore is found in an elliptical body 1400 feet in length and 160 feet in maximum width. This body is composed of alternating bands of high- and low-grade ore. The high-grade ore consists of massive magnetite, and the low-grade, of a mixture of magnetite and actinolite. The deposits are undeveloped. Some 2,500,000 tons of rock containing 60 percent iron, 8 percent silica, and 0.35 percent phosphorus are reasonably expectable, and another 2,500,000 tons are inferred."

The Raymond Mountain deposits were described by McLaughlin and Bradley [10] in 1916. Apparently, the only change has been in ownership. Prospects on Raymond Mountain formerly owned by Biladeau have become part of the Mt. Raymond mines. (See under lead-silver-zinc mines.)

Rising Sun, Dexter, Dexter South Extension, and Dexter East Extension, also called Sunrise Consolidated Lode, with a total area of 81.344 acres, lie mostly in the S½ sec. 14, T. 5 S., R. 22 E., M. D. They were patented in 1915 by George H. Myers. The Morning Star Consolidated group of six claims and a millsite, include 105.21 acres. They extend for 6,000 feet from the SW¼ sec. 6 to SW¼ sec. 7, T. 5 S., R. 23 E., M. D., and three of the claims lie partly in secs. 1 and 12, T. 5 S., R. 22 E., M. D. This group was patented in 1916 by George H. Myers. Both the Sunrise Consolidated and Morning Star Consolidated groups are now assessed to Vulcan Copper Company, c/o Fletcher & Brown, 21 East 40th Street, New York, New York. Formerly the Yosemite Copper Company did some of the work required for patent, and the present owner continued work, which included shafts or open cuts, adits or drill holes on each of the ten claims. Four core-drill holes were sunk on the Rising Sun claim and one on the Dexter claim, to depths as great as 225 feet. Though apparently located originally for copper, iron ore predominates so far, in the form of magnetite and sulfides. Work has not been extensive enough to estimate the extent of the ore, although some of the drill holes penetrated 50 to 100 feet of ore, in or near the contact of granodiorite and quartzite.

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[9] Trask, Parker D., and Simons, Frank S., Minarets magnetite deposits of Iron Mountain, Madera County, California: California Div. Mines Bull. 129, pp. 117-128, 1948.

[10] Op. cit., p. 554.

Teaford and Costa, c/o Otis Teaford, North Fork, report having iron claims near the Hart property, and Teaford states that hematite of good grade is available for sale.

Lead, Zinc, and Silver

Crown Point group (two northerly claims) and Fortuna group (three southerly claims) are held as locations by Charles W. Stewart, 410 Thorne Street, Fresno. They were formerly all listed as the Nidever group. These claims, in the Minarets district, have been described in a previous report.[11] In the northern group, prospects of zinc, lead, copper, and some silver were found. On the Fortuna claims south of Shadow Creek, high assays of lead and silver, and some zinc were obtained. Greater amounts of zinc were found farther up the mountain. The claims are at elevations near 10,000 feet. Work has been mostly in the form of open cuts and trenches, but two diamond drill holes, a shallow shaft, and some short drifts were run. Erwin [12] mentioned strong mineralization, principally in zinc, with lead, copper and some silver, for a width of 150 feet on the Crown Point and Crown Point No. 1 claims. Milling ore is said to extend for 1,000 feet.

Theodore G. Cappel has been doing some prospecting work on the claims during the past few years. This consisted principally of trenching. According to Stewart, work is to be continued during the summer of 1950.

Mt. Raymond mines, formerly called the Bradford group and the Biladeau property are in secs. 9 and 10, T. 5 S., R. 22 E., M.D., on Raymond Mountain. A mountain road from Fish Camp reaches one of the old claims. J. Wesley Smith, Box 777, Madera, and L. M. Bradford, Box 207, Madera, have eighteen locations, including the Star mine, which produced in 1889. Five of the claims, including the Star, are in the north half of section 10 and the rest in section 9 according to the owners.

Raymond Mountain and vicinity are covered largely by metamorphic rocks, [13] mostly quartzite. This has been intruded by granite, granodiorite, and other facies of igneous rocks.

A mill was built on Rainier Creek in section 16 late in 1888 and a tramway 7,000 feet long was built to it from the Star mine to deliver ore. This work was done by Shaw Mining and Reduction Company. Lead-silver ore from the Star mine was milled during the year 1889. The ore was estimated to be worth $17 a ton in lead and silver and the cost of mining, delivery to mill and milling was estimated at $1.75 a ton [14] before work started. Concentrate was saved with jigs and tables and shipped to Selby smelter. Mining was by open cut. The saving in the mill was evidently not as good as anticipated.

William Maguire and G. A. Wallerstedt made a report for the owners in 1940, in which, they estimated the Star mine contained 100,000 tons of exposed ore that could be milled. The ore carries lead, silver, and

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[11] Bradley, Walter W., The Minarets district, Madera County: California Min. Bur. Rept. 22, pp. 546-551, 1926.

[12] Erwin, Homer D., Geology and mineral resources of northeastern Madera County, California: California Div. Mines Rept. 30, pp. 7-78, 1934.

[13] McLaughlin, R. P., and Bradley, W. W., Madera County: California Min. Bur. Rept. 14, p. 532, 1916.

[14] California Min. Bur., Fresno County: California Min. Bur. Rept. 8, p. 216, 1888.

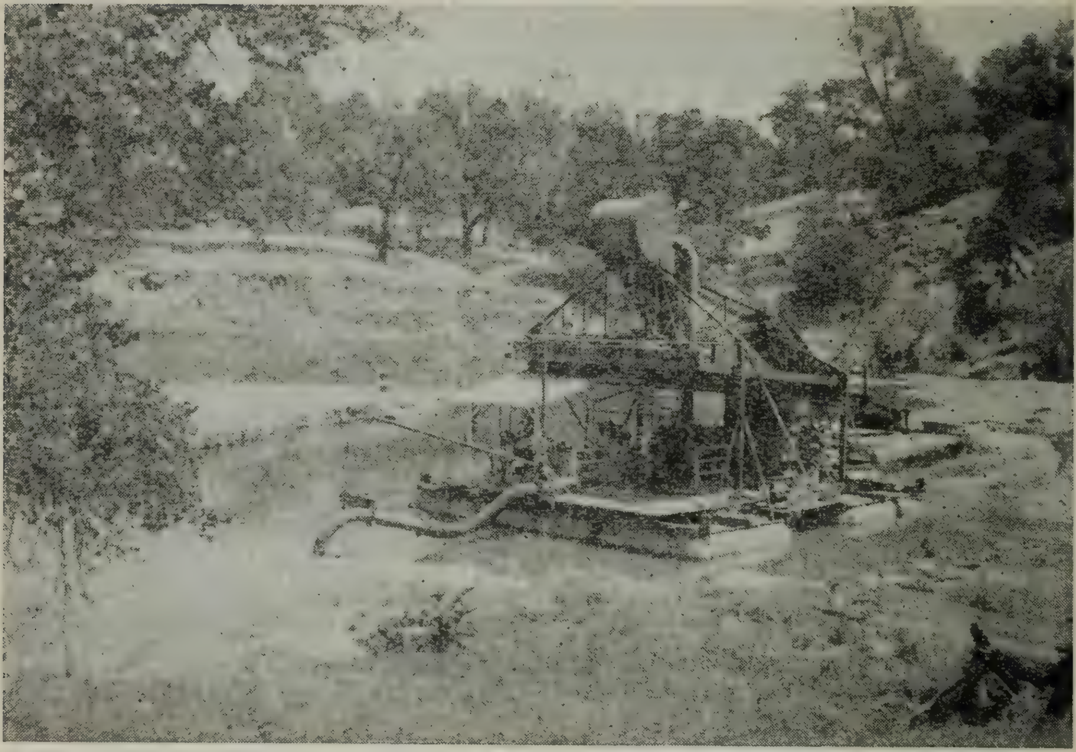

FIGURE 1. Chowchilla Dredging Co., 10-inch suction dredge, Chowchilla River, 7 miles above Raymond.

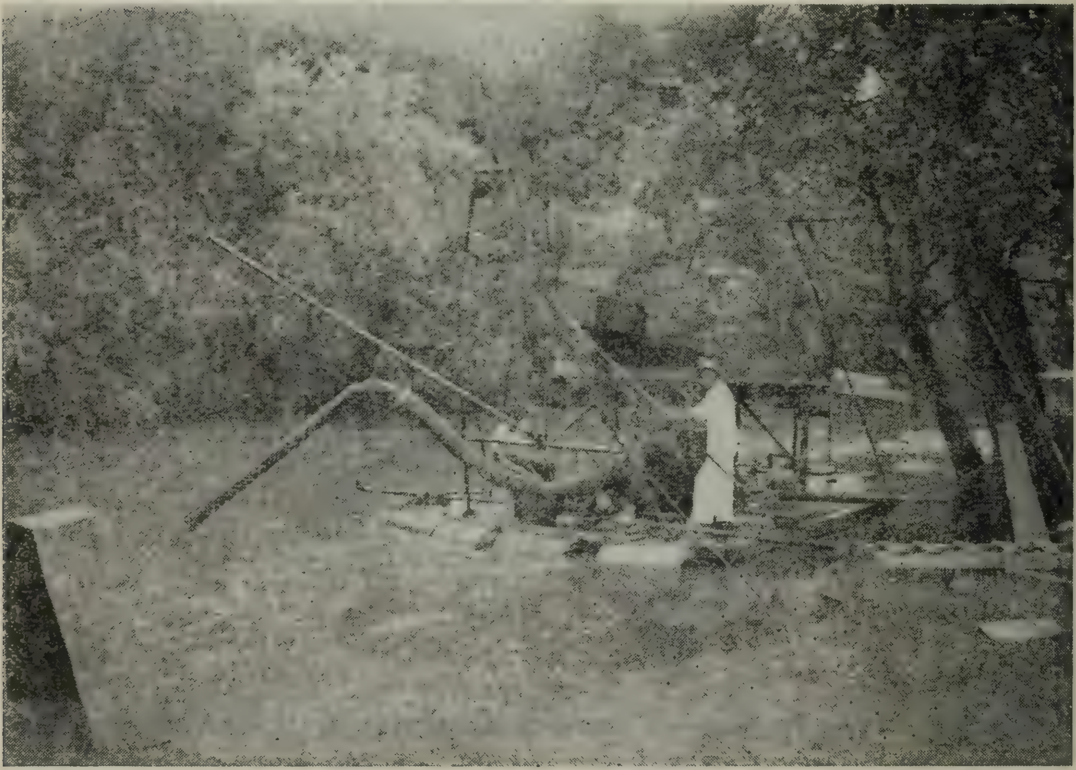

FIGURE 2. Suction dredge, 6-inch, Fresno River, at crossing of Coarsegold-Raymond road.

zinc which they think could be treated by preferential flotation. Their sampling was evidently meager, as only six assays were shown for the group of 18 claims. The ore is "highly silicified material with granodiorite walls and some inclusions of granodiorite in the ore body itself."

The Webber prospect, 2 miles south of the Star, shows a width of 6 feet carrying silver and zinc and very small amounts of gold, copper, and lead. A crosscut 40 feet below the surface was not completed to the vein. The Wawona and Yellowstone prospects are on the west side of Raymond Mountain and so far show "high grade sphalerite" but have not been developed. One assay indicated 14.93 percent zinc from the Wawona claim.

Limestone

No production of limestone has been recorded from Madera County, but more or less siliceous limestone and marble is indicated in the scheelite prospects in tactite which were found during the last war. Most of these are so far from railroads that it is unlikely they will prove of interest as sources of limestone. A list of these scheelite prospects and their locations are given by Jenkins.[15] Most of them are in the three tiers of townships in R. 22, 23, and 24 E., M.D., which are in the high Sierra Nevada region and in part astride the summit. The westernmost deposits (those nearest the railroad) are described below.

Chowchilla marble deposit is 3 miles from Grub Gulch on Chowchilla River, approximately in the northwest corner of T. 7 S., R. 20 E., M.D. It has been known for many years and has not been developed. It is 15 or 16 miles by road from Raymond; but the nearest railroad point now is Daulton about 8 miles south of Raymond.

R. & W. Tungsten Company claims in secs. 24 and 25, T. 7 S., R. 20 E., M.D., have had some scheelite production. The extent of the limestone outcrops is not known. These claims are 2 to 3 miles northwest of Coarse Gold.

Scott marble deposit is 6 miles east of Coarse Gold. The marble beds include a banded green and pink siliceous dolomitic marble.

Magnesite

White Top magnesite claim is in sec. 15, T. 7 S., R. 20 E., M.D., a fourth of a mile south of the former site of Grub Gulch. Mrs. E. C. Bronsert, Raymond, is the owner.

A stockwork of magnesite veinlets 2 to 2½ inches wide has been prospected by a shaft once 30 feet deep but now caved and filled to within 10 feet of the surface. The stockwork is now exposed for a width of six feet. No sales of magnesite have been made, and no work has been done recently.

Manganese

Claims were located for manganese about 1940 in six different townships in Madera County, as listed in Bulletin 125, of the California State Division of Mines. None of these had any commercial production. Below the surface showings of black oxide which attract the prospector, is rhodonite (manganese silicate), a quite common primary mineral at shallow depths in the Sierra Nevada region; rhodochrosite (manganese carbonate); and spessartite (manganese garnet). Most of the prospects were in Ts. 7 and 8 S., Rs. 21 and 22 E., and T. 9 S., R. 22 E., in remnants of pre-Cretaceous rocks overlying granite.

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[15] Jenkins, Olaf P., Tabulation of tungsten deposits of California to accompany economic mineral map No. 4: California Div. Mines Rept. 38, pp. 333-337, 1942.

The largest group of claims, made in October 1940 by Charles W. Stewart and Claude Nuss of Fresno, and Otis Teaford of North Fork, consisted of 57 locations in the Potter Ridge district, in T. 8 S., R. 21 E., M.D., on Thornberry Mountain. Some manganese oxide was found on the surface but within less than 20 feet in depth low-grade manganese silicates were encountered. Considerable work was done on the claims but according to Charles W. Stewart not enough ore was found to warrant holding the claims, and they were abandoned.

Natural Gas

The Pure Oil Company discovered dry natural gas in the Chowchilla area [16] first in 1934. The discovery well in sec. 7, T. 10 S., R. 14 E., M.D., is 8,399 feet deep and entered quartz diorite at 8,394 feet. Gas obtained from the Cretaceous sands between 7,925 and 8,060 feet in depth had a low calorific value, only 435 British thermal units. This gas has been used so far only for fuel while drilling other wells in the district. The above company drilled six wells in all. Three failed to give production, and three were completed as gas wells. The gas from the deep zone in the discovery well No. 1 ''Chowchilla,'' contains 42.54 percent methane and 56.99 percent nitrogen. Well No. 2 ''Chowchilla'' yielded gas from the Zilch (middle Miocene) zone between 2,400 and 2,700 feet in depth, and also from the Panoche formation (Upper Cretaceous) between 5,402 and 5,530 feet in depth. An estimate has been made only of the gas reserve of the Zilch zone, which showed 20,051,000 thousand cubic feet. This gas contains 97 percent methane, 1.4 percent nitrogen, 1.1 percent ethane, and 0.5 percent oxygen. Its calorific value is 950 British thermal units. So far, the wells of this area, which is 12 miles southwest of Chowchilla, have not been connected with any pipe line for use.

In 1943, the Texas Company drilled their well No. ''Gill'' 38-16 in sec. 16, T. 13 S., R. 16 E., about 16 miles southwest of Madera near San Joaquin River. It reached a depth of 9,154 feet at which point the bedrock complex was encountered. This proved to be the discovery well in what later was called the Gill Ranch gas field.[17] Natural gas of a calorific value of 960 British thermal units was found as deep as 5,760 feet, but production was established in Eocene sand between 4,419 and 4,485 feet. The above company later drilled five other wells; the Shell Oil Company, four wells; and the Natural Gas Corporation of California, one well.

During the same year, the Texas Company successfully completed their well No. ''Moffatt'' 1-7 in sec. 7, T. 12 S., R. 15 E., in what is known as the Moffatt Ranch area, 7 miles northeast of Firebaugh. Production from this well came from Eocene strata at depths between 3,930 and 3,935 feet.

Natural gas production from the county so far has been mostly from the Gill Ranch field where nine wells were in condition to produce in July 1948, but of which only five were in actual production. One of two potential producing wells[18] was being operated in the Moffatt Ranch area. At that time the gas reserve of the Gill Ranch field was estimated to be 31,136,385 thousand cubic feet.

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[16] Hodges, F. C., Chowchilla gas area: California Div. Oil and Gas Ann. Rept. 29, no. 2, pp. 7-11, 1943.

[17] Kaplow, E. J., Operations in District 5, 1943: California Div. Oil and Gas Ann. Rept. 29, no. 2, p. 68, 1943.

Pumice and Pumicite

The pumice and pumicite deposits in Madera County are in the vicinity of Friant. They are possibly Pleistocene lake deposits, in which pumice is principally in the upper strata. The pumicite below it shows horizontal color banding due to changes in conditions of sedimentation. Pumicite is the very finely divided product of volcanic eruptions of explosive type, and may be carried long distances in the air as dust, or may be transported by water. Pumice is a frothy volcanic glass. Its vesicular structure is a result of volcanic gases in the lava expanding when pressure is relieved at the time of eruption. In composition, pumice and pumicite are similar to granite and granodiorite.

Pumice and pumicite are both employed as abrasives, but much less has been consumed for this purpose in recent years. The most marked increase in use has been with concrete. Pumice aggregate is used with concrete to give light-weight products with improved insulating and fire-resistant properties and saving in construction costs. Pumicite used as an admixture and to replace part of the portland cement has also come into use in substantial quantities especially in mass concrete and in work exposed to water. Other uses of pumicite are as filler and carrier for insecticides, and filler in paints, plastics, and plasters. In Madera County, two properties are producing pumice for use with portland cement in making light-weight brick. These are to be employed principally in building small dwellings. One property is producing pumicite which is used as a filler and carrier for both liquid and dry insecticides. Some pumice is also used in making concrete pipe. Two other properties described herein, one that produced pumice and one pumicite, were idle in February 1950.

California Industrial Minerals Company, Forrest S. Taylor, general manager, Friant, works a pumicite deposit in the NE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 1, T. 11 S., R. 20 E., M.D., 2 miles northeast of Friant, and operates a drying and sacking plant at Friant. The land containing the deposit is assessed to Forrest S. and Louisa M. Taylor.

Overburden up to 20 feet thick consisting of soil mixed with lump pumice has been stripped from the volcanic ash on part of the tract. A face of the material 27 feet high was being worked in October 1948. It is blasted, then dug and loaded on trucks by a $\frac{1}{2}$-cubic yard gasoline shovel, and hauled to the plant at Friant. In the bank, the volcanic ash varies from reddish brown to white but dries nearly white. It shows horizontal color bands from $\frac{1}{6}$ inch to 2 inches thick.

At the plant, a furnace burning crude oil heats air which is driven by a fan to a heater for drying the pumicite. This is all that is necessary to break the bond of moisture which holds the fine particles together. A Multiclone dust collector recovers most of the pumicite. This portion, marketed in 101-pound paper bags under the trade name Frianite AC3X averages about 85 percent through 325 mesh. The small amount of finer material reaching the bag-house nearly all passes 325 mesh and is sold as Frianite B4X.

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[18] California Div. Oil and Gas, Production statistics of California oil fields: California Div. Oil and Gas Ann. Rept. 34, no. 1, p. 36, 1948.

The pumicite is widely used as a filler and carrier for insecticides, both dry and liquid, including those used for crop dusting by airplanes. The plant capacity is about 50 tons in 8 hours. A total of 5 to 7 men are employed at the quarry and plant.

Elmer Erickson, P. O. Box 98, Friant, operates a pumice deposit and a pumice brick plant on 135 acres of land in Madera County in sec. 1, T. 11 S., R. 20 E., M.D., which is assessed to Mrs. Eva V. Erickson. Friant railroad station is 2 miles away by road, but most shipments are made by truck.

The pumice deposit is reported to be 30 feet deep and underlain by sand and pumicite. There is a soil overburden of 2 or 3 feet. The deposit is a partly cemented pumice conglomerate. Most of the pebbles are less than 2½ inches in diameter. These pebbles, originally light grey to white, have been superficially stained by iron oxide from the thin overlying soil layer and from the finer interstitial material so that the whole mass is light red, and finished bricks have a light terra cotta color.

The pumice is dug with a rooter pulled by a D 7 Caterpillar tractor and is stock piled by tractor under a shed. A chute feeds a belt conveyor which delivers pumice to a vibrating screen of ⅝ inch mesh. Fines through the screen are taken by a short belt conveyor to a hopper where a bucket elevator lifts pumice 25 feet to a second belt conveyor. This distributes it to roofed wooden storage bins holding several hundred cubic yards. Coarse pumice passes over the screen to a Williams patent crusher and pulverizer and to the elevator. The screen size range of most of the pumice is from ¼-inch to dust.

Three sizes of brick, used mostly in small dwellings, are made in the brick plant. These are 4 by 6 by 12 inches, 4 by 8 by 12 inches, and 4 by 8 by 16 inches. A stiff mixture, containing five parts pumice to one part portland cement is used. Bricks are made in Flamm machines. The bricks are held twelve hours in seven steam chambers, 10 by 10 feet, then kept moist in the open air by sprinkling with water for three days. This is followed by 30 days dry curing in the open air. From 6 to 13 men are employed.

Pumice has been sold to many other brick makers who haul by truck as far as Sacramento. The pumicite underlying the pumice is not being worked at present.

The pumice and pumicite deposits on the Edw. A. Wagner Ranch in sec. 6, T. 11 S., R. 21 E., M.D., about 1 mile north of Friant, are operated by Pumice Industries in the dry season. The main office is in the Press Building, Oakland 7, California. Hugh T. Harrison is president.

The pumicite deposit, on a hillside at an elevation of about 500 feet, has been exposed by bench workings 600 feet long, and up to 40 feet deep. Work so far has advanced only 40 feet into the hill. The whitest volcanic ash, of fine grain size and uncemented, is 12 to 15 feet thick on the east end of the bench. It shows ripple marks and is overlain by an off-white layer, which is probably stained by the thin soil above. It is underlain by clay. Farther southwest the volcanic ash is slightly off-white but apparently of good grade. Below it for 10 feet are flat alternating layers of pinkish-brown clay 1 inch to 4 inches thick and ash up to 12 inches thick.

The property was deserted temporarily February 24, 1950.

Pumicite was evidently dug by tractor and bulldozer, and a rotary kiln 50 feet long had been brought in for drying, but did not appear to have been used recently. The pumicite was elevated to a bin from which it was drawn into 100-pound paper bags for sale. It has been used in concrete products and as an abrasive. The plant is operated by electric power.

A few hundred feet southwest on a hilltop, a small deposit of pumice, similar in character to that on the Erickson land has been worked. The pumice is delivered to a small bin on the hillside, going thence by belt conveyor to triple rolls 2 by 2½ feet, and by another belt conveyor to a screen and to a loading chute which serves trucks on the road below. The product as sold to brick makers ranges from ¼ inch to dust.

Pumicrete Sales Company and Pumicrete Products Company operate under lease on 860 acres of the Arnold Ranch (formerly Goble Ranch) in sec. 3, T. 12 S., R. 20 E., M.D., near San Joaquin River, 17½ miles southeast of Madera by road. W. E. Schlink, 1511 O Street, Fresno, is general manager. A lease is also held on mineral rights on 480 acres of the Cobb property, 2 miles south of the above area.

Pumice and pumicite deposits are in rolling foothills. So far (October 1948) the pumice, which is in the upper part of the section and is overlain by little overburden, has been mined. A bank 60 feet high is worked with a Bucyrus Erie steam shovel using oil fuel. Pumice is delivered by trucks to the brick plant after it is crushed in rolls. From a pit it is lifted by bucket elevator to a motor mixer of 52 cubic feet capacity, run by a 15-horsepower motor. The plant is equipped with several machines for making bricks and blocks in 54 shapes and sizes, as well as shingles and floor tile. Capacity exceeds 5,000 bricks a day. The shingle machine has a daily capacity of 3,500 shingles ⅞ inch by 8 by 19 inches. A mix of about 1 part cement to 5 parts pumice is used and bricks are air-dried 3 to 4 weeks after sprinkling 5 to 10 days. The product is extensively used in San Joaquin Valley especially for dwellings. From 7 to 22 men are employed.

Dave Smith, Friant, operates part time a pumice deposit on the Urrutia and Fulton land in sec. 1, T. 11 S., R. 20 E., M.D., 1½ miles northwest of Friant.

A dragline operated by a gasoline engine brings the material to a grizzly with 5-inch spacing. The fine material passing through the grizzly falls in a hopper and is taken by a short belt feeder to a pair of rolls with 27-inch faces. After being crushed the material is taken by an inclined belt conveyor about 50 feet long to a wooden storage bin fitted with a chute for loading trucks.

Stone (Miscellaneous)

No large or regular production of rock, sand, or gravel has been made in the county in recent years. In the sections where the county maintains dirt roads, local stream gravel or crushed stone have been utilized.

Big Ben and Big Ben No. 1 claims are on Fine Gold Creek at Fine Gold in sec. 31, T. 8 S., R. 22 E., M.D. Otis Teaford, North Fork, is the owner. Teaford has produced several thousand tons of gravel and sand from these claims for local use.

Buchenau building stone quarry is reached by traveling 13 miles northeast of Madera on the Raymond road, and turning westward.

Madera County for many years has used crushed waste granite from the quarries near Raymond for road work. A rock crusher has been operated at the McGilvray quarry for this purpose and is still there.

Tungsten

Of the numerous minerals containing tungsten, wolframite [(Fe,Mn) WO_4], and scheelite ($CaWO_4$) have been most important commercially. In California, practically all commercial production of tungsten has been in the form of scheelite or concentrate containing 60 percent or more of that mineral. However, the first tungsten ore produced from Madera County was several tons of hübnerite from the Minarets district about 1917. This mineral, manganese tungstate, is generally classed as a variety of wolframite in which the manganese greatly exceeds the iron content. Wolframite has also been known for a long time at the old I.X.L. copper mine in the lower foothills of Madera County, but has not been produced commercially there.

No scheelite from Madera County was mentioned in any of the available literature before the last war, when many prospects were found. The first production, of only a few tons, was reported in 1941. From 1943 to 1945 inclusive, the Strawberry mine was the principal producer, and several others made small contributions. The total production reported for the 3-year period was about 310 tons of concentrate. No scheelite production was reported in 1946 and 1947, but in 1948 the Strawberry mine was reopened and some scheelite concentrate was shipped late in the fall.

Tungsten minerals are formed under a variety of conditions. Some scheelite has been found in quartz veins in this region, but most is found in contact metamorphic (pyrometasomatic) deposits, formed by the action of heat and solutions from intrusive granitic magma of not too acid type, on limestone. The limestone layers are part of the Carboniferous series and possibly other pre-Cretaceous rocks which overlie the Sierra Nevada batholith along the entire western front of these mountains. Along this slope from Mariposa County southward, erosion of this originally thick mantle of older rocks has been carried much nearer completion than farther north. Over wide areas, the older rocks have been completely removed. Elsewhere, erosion has exposed the contact zone between the granodiorite and limestone, where metamorphic action has been sufficiently intense to form a new series of minerals resulting in a rock commonly called tactite. This rock is characterized by a wide variety of silicate minerals among which reddish-brown garnet, green epidote, and black hornblende will be first noted by the prospector. If scheelite occurs it is generally one of the metamorphic minerals in this tactite, although it may occur nearby in quartz veins. The tactite may also contain diopside, idocrase, quartz, fluorite, and titanite. On the limestone side of the contact, the tactite is succeeded by such lime silicates as wollastonite and tremolite. Molybdenum in very small amounts is common. The scheelite in this region is generally not distinctive enough to be readily differentiated by inspection from quartz and other white minerals likely to be present, so the use of the ultraviolet lamp is always advisable in prospecting, mining, and sorting ore.

Owing to fracturing, solution, and metamorphism of the limestone and dolomite, the scheelite deposits are likely to be irregular in shape, erratic in scheelite content, and expensive to prospect and mine. Their possible persistence in depth depends, of course, on the downward extension of the limestone. If the latter has been folded or faulted so that it has been protected from erosion by the surrounding granodiorite, the deposit may extend deeply enough to justify mining through a shaft.

Although some high-grade lump ore carrying 5 percent WO_3 was found, most of the ore mined ranged from 1½ to 1 percent or less of WO_3 and required milling and concentration. In some cases, further treatment or reconcentration was required to bring the product to acceptable grade. Specifications called for 60 percent WO_3 in scheelite concentrate, with minor fractions of 1 percent of copper, arsenic, phosphorus, bismuth, molybdenum, tin, sulfur, antimony, and lead and 1 percent manganese permitted without penalty.

Notice of termination of the domestic tungsten program was issued to be effective March 31, 1944, which, except for special cases, meant the end of payment of $30 per short ton unit for scheelite concentrate. Market prices since then have not been high enough to encourage operation of small, low-grade tungsten mines and prospects.

In the present state of development, which consists in most cases of shallow shafts, open cuts, and short adits, nearly all of the tungsten workings in Madera County should be classed as prospects. Many of these are on patented land where no assessment work has to be done. Only a few of the unpatented claims which may have been kept in good standing by assessment work can be identified with claims which were mentioned in the list of properties active in 1941.[19]

The present price for scheelite concentrate does not offer any inducement for the development of the grades of ore now known to exist in these idle prospects. In most cases also, the amounts of ore available do not justify the expense of erecting on individual properties the type of milling and concentrating equipment needed to produce an acceptable product under present specifications. Before the possibilities of this region as a source of tungsten can be fully realized, it will be necessary to raise the price paid the producer and also provide some central plant where rough concentrates can be put in marketable form.

Edward E. and G. R. Carothers, South Fork, have filed proofs of labor for $3,500 on a large group of tungsten claims in secs. 3, 4, and 10, T. 8 S., R. 24 E., M.D. These claims have not produced since 1944. The work has been principally done by tractor and bulldozer. The claims are named Crystal 1 to 6, Crystal A & B, Garnet 1 to 5, Tungsten A to L, etc. They are in the vicinity of the Rock Creek road and Fish Creek, where the latter flows eastward into San Joaquin River. There is a 10-ton mill on one of the claims.

Cedar scheelite claim is in sec. 12, T. 7 S., R. 22 E., M.D., about 3 miles northeast of Bass Lake on ground formerly held by Jess Love as the Dogwood mines. Considerable unsuccessful work was done by Love with a tractor and bulldozer. The claim is at an elevation of 6,200 feet. J. G. Kossan, Box 35, Friant, is the present owner.

Kossan has followed a promising showing of scheelite to a depth of 50 feet in a shaft, with scheelite in spots over a width of 6 feet. He has taken out 1 ton of concentrate. Equipment includes a 1-drill air compressor and drill, gasoline engine, 6-inch rock crusher, a set of 18-inch rolls, and homemade concentrator.

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[19] Jenkins, Olaf P., and others, Tabulation of tungsten deposits, Madera County: California Div. Mines Rept. 38, pp. 333-337, 1942.

Strawberry tungsten mine is 85 miles by paved highway and dirt road from Madera, in what would be sec. 36, T. 4 S., R. 24 E., M.D., and adjoining sections if surveyed, at an elevation of about 7,500 feet, a short distance north of Clover Meadow Ranger Station. Eleven claims called Strawberry No. 1 to 11A inclusive, were located in 1941 by J. E. Cobb and J. A. McDougald. They were leased to D. W. Haggerty and C. F. Madden (Northumberland Mining Company), Tonopah, Nevada. These lessees erected a 50-ton plant for milling and gravity concentration in the summer of 1943 and began production in September 1943, shipping 3 carloads of scheelite concentrate by December 1943. The working season is short because of the elevation. In 1944, Haggerty and Madden reported doing $50,000 worth of work, including open pit excavation of 5,000 cubic yards for ore removal, the driving of 180 feet of tunnels, and addition of a flotation outfit to the mill. However, production fell off 31 percent from 1943, and in 1945 the output was again sharply reduced. No production was reported for 1946 and 1947. The premium price of $30 a unit of WO_3 had been discontinued April 30, 1944, at which time the market price was $24 a unit, offering little incentive to producers.

Scheelite is in small bodies of tactite at several places, but most of the work has been done on Number 1 claim, just east of the camp. The work has been mostly in the form of open cuts, and the principal workings numbered 1 to 3 inclusive are on the northeast quarter of the claim. Number 5 is farther south on the same claim and Number 4 is on another claim. All except Number 4 were opened and worked by Haggerty and Madden. Number 2 open cut yielded ore averaging 3 percent WO_3 and supplied the carloads of concentrate shipped in 1943. Number 1 working was on an ore body 110 feet long by 15 feet in average width, striking north along a marble-granite contact zone and dipping 80° west. This was worked to a depth of about 50 feet by open cut, from the bottom of which a level was run about 120 feet and some stoping was done. A shaft was also sunk to a depth of about 50 feet below the pit level on the north end of the ore. The ore here was reported to carry about 2 percent WO_3.

In 1947, Bradley Mining Company drilled the Number 4 deposit but did not mine the ore indicated by this prospecting. In the summer of 1948, Fresno Mining Company, 415 Brix Building, Fresno, took a sublease on the claims from Haggerty and Madden and began work. The mill was started on ore from the Number 4 deposit September 1 and some shipments of concentrate were made that year. A crew of 30 men were employed, partly on surface and shaft work, under the direction of A. R. McGuire, president of the company and Ray Henricksen, superintendent. In 1948 also, the U. S. Bureau of Mines had a diamond-drilling crew on the property during September and October. They drilled 8 holes aggregating 1,937 feet. These holes were all on Number 1 claim. The results of this drilling are given in Report of Investigations 4543, Investigation of the Strawberry tungsten deposit, Madera County, California, published by U. S. Bureau of Mines, September 1949.

Otis Teaford of North Fork, owner of the Teaford Claims, in 1944 worked a claim on Fish Creek Mountain, sec. 10, T. 9 S., R. 22 E., M.D.

Two adits, 30 feet and 100 feet long, were run. In the longer one, two ledges or stringers carrying scheelite were found. Work was also done with a tractor and bulldozer and scheelite was sorted from a dozen places. The ore was milled by O. E. Aversi at Coarse Gold. Teaford and C. S. Brumbaugh also have the Black Eagle claim in secs. 4 and 5, T. 7 S., R. 22 E., M.D. A mill was built there but never used. He estimates he has 300 to 400 tons of scheelite ore on the Teaford Ranch, in secs. 32 and 33, T. 7 S., R. 22 E., M.D.

Wissman claims (3) were located in December 1940 by Clayton Wissman. They are half a mile east of the Chiquito trail, in the W½ sec. 3, T. 8 S., R. 24 E., M.D., just north of Fish Creek. A small mill was put on the claims in 1942, and some production was made. No work has been reported recently.

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Asbestos

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral products	Remarks and references *
			Sec.	T.	R.	B and M		
1	Deep Canyon	Mrs. Nellie Alexander, Ahwahnee	14	7S	20E	MD	Asbestos	Prospect only. Idle.

Copper

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral products	Remarks and references *
			Sec.	T.	R.	B and M		
2	Buchanan Copper mine	U. S. Smelting, Refining, & Mining Co., Newhouse Bldg., Salt Lake City, Utah	34	8S	18E	MD	Copper	R. 11, pp. 218, 223; R. 13, p. 59; B. 50, pp. 269-276; R. 14, p. 538.
3	Daulton mine	Mrs. Agnes M. Bradford, Box 207, Madera	35	9S	18E	MD	Copper	B. 18, p. 149; B. 50, p. 270; R. 14, p. 538; R. 17, p. 83; R. 24, p. 322; B. 144, p. 262.
4	Jessie Bell mine	Daulton & Buchenau Est.	13	9S	18E	MD	Copper	R. 24, p. 323; B. 144, p. 262.
	Victory	P. Rosati, Raymond		8S	19E	MD	Copper	B. 144, p. 264. Not shown on map.

Feldspar

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral products	Remarks and references *
			Sec.	T.	R.	B and M		
5	Carol Jane mining claim	Myra Anderson, 1405 N. Fresno St., Fresno	15, 21 22	7S	22E	MD	Feldspar	

Gold

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral products	Remarks and references *
			Sec.	T.	R.	B and M		
6	Adobe Ranch	H. E. Larsen, Rt. 4, Box 349, Madera, and Dr. W. G. Hughes, San Rafael, lessees	17, 18	10S	19E	MD	Gold	
7	Bimbo Extension #5 and #6	Melvin Mines, Inc.	4, 5 32, 33	8S 7S	21E 21E	MD MD	Gold	
8	Enterprise mine	Ota P. Lightfoot, Trustee	12	7S	21E	MD	Gold	R. 14, pp. 539, 542; R. 18, p. 303; R. 24, p. 326; R. 31, p. 24.
9	Flori Ori Gold Lode claim	Orville T. Hallan	31	6S	21E	MD	Gold	
10	Gambetta and Arkansas Traveler	May M. Lester	15, 16	7S	20E	MD	Gold	R. 10, pp. 197-198; R. 13, p. 208; R. 14, pp. 543-544.
11	Golden Crystal Lode Gold & Lucky Strike Lode claims	Harvey Baylor & Phillip & Mattie Shirk	18	9S	20E	MD	Gold	

12	Golden Ribbon No. 1 and No. 2	John A. Hassell	30	7S	21E	MD	Gold	
13	Golden Treasure and other claims	Clem & Beverly Mecchi	10, 15	7S	20E	MD	Gold	
14	Jeff Davis and Canary	MV., Barbara & Benita Day, and C. N. Ward	15	7S	20E	MD	Gold	
15	Keystone Lode claim	J. Wesley Smith, Box 777, Madera	10	5S	22E	MD	Gold	
16	Madera #1 claim	H. N. & F. A. Bradshaw & W. C. Eadwards, 31 E. Gabilan St., Salinas, and Victor H. Butler, P.O. Box 341, Monterey	19	10S	22E	MD	Gold	
17	Morning Star mining claim	Wayne S. Clanton	23	7S	20E	MD	Gold	R. 14, p. 548.
18	Mountain Lily #1, Mary, North Star et al.	Wm. C. Melvin	30, 31	7S	21E	MD	Gold	R. 12, p. 161; R. 13, p. 211; R. 14, p. 547.
19	Mud Springs mine	Wm. P. Lasher, 4211 Ball Ave., Fresno	26	9S	21E	MD	Gold	R. 12, p. 161; R. 13, p. 211; R. 14, p. 548; R. 24, p. 324; R. 31, p. 25.
20	Owl #1 & #2	Edward, Arthur and Harry Behlen	29	7S	21E	MD	Gold and silver	
21	Quartz Mountain	Various	33	8S	21E	MD	Gold	R. 8, p. 210; R. 12, p. 162; R. 13, p. 212; R. 14, p. 549.
22	St. Patrick & Josephine	Henry Investment Co.	15, 16	7S	20E	MD	Gold	R. 8, pp. 213-214; R. 10, pp. 202-203; R. 13, p. 209; R. 18, p. 304; R. 21, p. 25.

Gold (Continued)

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral products	Remarks and references *
			Sec.	T.	R.	B and M		
23	Savannah, et al claims	H. U. Maxfield, 1611 Russ Bldg., San Francisco	13, 14 23, 24	7S	20E	MD	Gold	R. 12, pp. 158, 162; R. 13, pp. 212, 213; R. 14, p. 550.
24	Sunset View	Earl M. & Margaret E. Nave, Box 35, Wishon	17	7S	22E	MD	Gold	
25	Texas Flat Consolidated mine	Wm. Krohn, Coarsegold	6 31	8S 7S	21E 21E	MD MD	Gold	R. 8, p. 212; R. 12, p. 164; R. 13, p. 213; R. 14, p. 551; R. 18, pp. 304, 305; R. 24, pp. 325-326; R. 31, p. 25.
26	Waterloo mine (6 claims)	Paymaster Mining Co.	15, 23	8S	21E	MD	Gold	R. 11, p. 216; R. 12, p. 161; R. 13, p. 211; R. 14, pp. 552-553; R. 31, pp. 25-26.
27	Williams & Santoni dredge	F. Williams, Clovis, F. Santoni, Rt. 13, Box 258, Fresno	7	11S	21E	MD	Gold	

Granite

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral products	Remarks and references *
			Sec.	T.	R.	B and M		
28	Madera quarry	Operated 1938-42 by Madera Quarries Co. (withdrawn 1946)	16	9S	20E	MD	Granite	Idle.
29	McGilvray quarry	Alex B. McGilvray, Raymond	27	8S	19E	MD	Granite	R. 12, p. 384; R. 13, p. 620; B. 38, p. 32; R. 14, pp. 562-563.
30	Raymond Granite quarry	M. Davidson, c/o Dan McCarty, 6450 Camden St., Oakland	22, 23	8S	19E	MD	Granite	R. 10, p. 189; R. 12, p. 384; R. 13, p. 620; B. 38, pp. 30-32; R. 14, pp. 565-566.

Iron

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral products	Remarks and references *
			Sec.	T.	R.	B and M		
31	Dexter	Vulcan Copper Co., c/o Fletcher & Brown, 21 E. 40th St., New York City	14	5S	22E	MD	Iron	
32	Hart Iron deposit	Helen Hart Waisanen & Ruth Hart Rotherham, 330 Lexington Way, Burlingame, Calif.	15, 22	5S	22E	MD	Iron	B. 38, p. 298; R. 10, pp. 191-193; R. 11, p. 214; R. 14, p. 554; R. 24, pp. 336-337.
33	Minarets Iron deposit or Iron Mountain group (10 claims)	Last known owner: Noble Electric Steel Co., San Francisco	1 7 (Unsurv	4S 4S eyed, ap	25E 26E prox.)	MD MD	Iron Iron	R. 14, pp. 555-558; R. 24, pp. 341-343; R. 30, p. 73; B. 129, pp. 120-128.
34	Morning Star Consolidated group	Vulcan Copper Co., c/o Fletcher & Brown, 21 E. 40th St., New York City	1, 12 6, 7	5S 5S	22E 23E	MD MD	Iron	R. 24, p. 336.
35	Rising Sun	Vulcan Copper Co., c/o Fletcher & Brown, 21 E. 40th St., New York City	14	5S	22E	MD	Iron	
36	Stewart & Nuss	Chas. Stewart and Claude Nuss	9	5S	22E	MD	Iron	

Lead, Zinc, Silver

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral products	Remarks and references *
			Sec.	T.	R.	B and M		
37	Crown Point	Charles W. Stewart, 410 Thorne St., Fresno	Minarets District Unsurveyed				Lead, zinc, silver	R. 22, pp. 547, 548; R. 24, pp. 340, 341; R. 30, pp. 73-74.
38	Fortuna group	Charles W. Stewart, 410 Thorne St., Fresno	Minarets District Unsurveyed				Lead, zinc, silver	R. 22, pp. 547-548; R. 24, pp. 340-341; R. 30, pp. 73-74.
39	Mount Raymond mines (formerly Star, Bradford, and Biladeau)	J. Wesley Smith and L. M. Bradford, Box 777, Madera	9, 10	5S	22E	MD	Lead, zinc, silver	

Magnesite

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral products	Remarks and references *
			Sec.	T.	R.	B and M		
40	White Top magnesite claim	Mrs. E. C. Bronsert, Raymond	15	7S	20E	MD	Magnesite	Prospect, idle.

Manganese

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral products	Remarks and references *
			Sec.	T.	R.	B and M		
41	Yukon Jake, Stewart et al. (57 locations)	Otis Teaford, Claude Nuss, and Chas. W. Stewart	36 1, 2	7S 8S	21E 21E	MD	Manganese	Abandoned.

Natural Gas

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral products	Remarks and references *
			Sec.	T.	R.	B and M		
42	Chowchilla Ranch area	Discovery by Pure Oil Company	7	10S	14E	MD	Natural gas	Wells shut in.
43	Gill Ranch area	Discovery by the Texas Company	16	13S	16E	MD	Natural gas	5 producing wells, 1948.
44	Moffatt Ranch area	Discovery by the Texas Company	7	12S	15E	MD	Natural gas	1 producing well, 1948.

Nickel, Cobalt

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral products	Remarks and references *
			Sec.	T.	R.	B and M		
45	Nickel and cobalt	E. W. Krohn, Coarsegold	23, 26	10S	19E	MD	Nickel cobalt	Prospect.

Pumice

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral products	Remarks and references *
			Sec.	T.	R.	B and M		
46	Erickson pumice	Mrs. Eva V. Erickson	1	11S	20E	MD	Pumice	Active, 1950.
47	Smith pumice	Urrutia & Fulton, owners. Dave Smith, Friant, lessee	1	11S	20E	MD	Pumice	Idle, Feb. 1950.

Pumicite

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral products	Remarks and references *
			Sec.	T.	R.	B and M		
48	Arnold pumicite	Pumicrete Products Co., W. E. Schlink, mgr., 1511 O St., Fresno, lessee	3	12S	20E	MD	Pumicite	Active, 1950.
49	Taylor pumicite	Forrest S. & Louisa M. Taylor	1	11S	20E	MD	Pumicite	Active, 1950.
50	Wagner pumicite	Pumice Industries, Press Bldg., Oakland 7, lessee	6	11S	21E	MD	Pumicite	Idle, Feb. 1950.

Miscellaneous Stone

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral products	Remarks and references *
			Sec.	T.	R.	B and M		
51	Big Ben, Big Ben No. 1	Otis Teaford, North Fork	31	8S	22E	MD	Miscellaneous stone and gold	

Tungsten

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral products	Remarks and references *
			Sec.	T.	R.	B and M		
52	Black Eagle	Oris Teaford and C. S. Brumbaugh, North Fork	4, 5	7S	22E	MD	Tungsten	
53	Carothers claims	Edward E. and G. R. Carothers, North Fork	3, 4 10	8S	24E	MD	Tungsten	
54	Cedar claim	Joe G. Kossan, Box 35, Friant	12 (approx)	7S	22E	MD	Tungsten	Small producer, 1949.
55	Church	Denver Church	9	8S	22E	MD	Tungsten	
56	Ellis	Chas. Ellis & Harris	10	8S	22E	MD	Tungsten	
57	Fish Creek Mountain tungsten lode	Willy Hoague	9 or 10	9S	22E	MD	Tungsten	
58	Ghost Canyon group (12 claims)	John H. Walker	36 31 1 6	4S 4S 5S 5S	23E 24E 23E 24E	MD MD MD MD	Tungsten Tungsten Tungsten Tungsten	R. 38, pp. 295, 333.
59	Jones Ranch	Tom Jones	13	7S	20E	MD	Tungsten	
60	Love and Iverson claim	Love and Iverson	13	7S	22E	MD	Tungsten	See Cedar claim.
61	Nutter #1 and #5 incl.	Ernest B. Smith, Raymond	21	6S	20E	MD	Tungsten and gold	
62	Rapp and Company	Tom Jones	29	7S	21E	MD	Tungsten	
63	Seller's mine	Claude Sellers	29	6S	23E	MD	Tungsten	

Tungsten (Continued)

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral products	Remarks and references *
			Sec.	T.	R.	B and M		
64	Strawberry tungsten mine (Includes Strawberry claims #1 to #9 incl., 10A & 11A)	J. E. Cobb & J. A. McDougald (Subleased to Fresno Mining Co., 414-415 Brix Bldg., Fresno, by first lessee Northumberland Mining Co.)	36 6	4S 5S	24E 25E	MD MD	Tungsten	A producer 1948-49.
65	Teaford Ranch	Otis Teaford	32, 33	7S	22E	MD	Tungsten	
66	Tin Bucket	J. R. Hossack	7	6S	22E	MD	Tungsten	
67	Walker group	Walker Tungsten Mines, Inc.	7	5S	24E	MD	Tungsten	
68	Welsh Ranch tungsten	H. H. Welsh, Rowell Bldg., Fresno	32, 33 3, 4 10	8S 9S	22E 22E	MD MD	Tungsten	
69	Wissman Brothers	Clayton Wissman, W. W. Knowles	4	8S	24E	MD	Tungsten	

* Division of Mines Publications. R = report, B = bulletin.

MINING LAW IN RECENT YEARS*

By William E. Colby**

SWAMP AND OVERFLOWED LANDS[1]
LAND GRANTS TO STATES—Continued

The federal government's great liberality in its gifts of public lands to the states is further evidenced by its grants to them of Swamp and Overflowed lands. The first grant of this sort was made to Louisiana, March 2, 1849.[2] The year following, September 28, 1850,[3] Congress passed a similar act which, though its opening provisions designate only the State of Arkansas as the beneficiary, was by its final section extended to and its benefits conferred on each of the other states then in existence in which such swamp and overflowed lands were situated.[4] This Act of 1850 is the basic law on the subject. It was a gratuity to the states to encourage the construction of the necessary levees and drains essential to reclaim such lands and render them fit for cultivation and use.[5] Swamp lands already sold by the United States at the date of the act were excluded from the grant. Section 2 imposed on the Secretary of the Interior,[6] as soon as practicable, the duty of making lists and plats of such lands and transmitting the same to the governors of the respective states and upon request of such governors to issue patents to the states, whereupon ''the fee simple to said lands shall vest in the state,'' subject to disposal by the state legislature. The proceeds from such disposal were ''as far as necessary'' to be applied to reclaiming the lands. Section 3 defined swamp and overflowed lands as those legal subdivisions of the public domain the greater part of which were ''wet and unfit for cultivation.''[7]

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* This is the third of a series of articles intended to supplement the 3d edition of Lindley on Mines (1914) and brings the subject to date. The first article appeared in September, 1945, in 33 Calif. L. Rev. 368-387, and in the California Journal of Mines and Geology, vol. 44, pp. 279-292, July 1948. The second article appeared in September, 1949, in 36 Calif. L. Rev. 355-389, and in the California Journal of Mines and Geology, vol. 45, pp. 465-490, July, 1949.

** Member of the San Francisco Bar; Lecturer on the Law of Mines and Waters, University of California, 1911-1937; LL.D., University of California, 1937; Assistant Editor, Lindley on Mines (3d ed. 1914).

[1] For some unaccountable reason Lindley on Mines does not deal with this class of land grants to the states. The only explanation this writer can suggest for the omission is that when Judge Lindley wrote his outstanding work on mining law, swamp and overflowed lands were, for the greater part, situated remote from regions of mining activity and no conflict of rights had then occurred or seemed imminent. It is only in recent years that some of these swamp lands have proved to be valuable for petroleum and gold dredging. Because of their complete omission from consideration in Lindley on Mines, this article will deal more comprehensively with this class of land than would otherwise be the case. However, since a volume could be devoted to the law on the subject, only the salient features will be presented. Those desiring to pursue the inquiry further are referred to 43 U. S. C. Chaps. 23 and 24 (1946); 50 C. J. 996-1023; 21 Cal. Juris. 681-684; 19 New Cal. Juris. 433-450; Cal. Pub. Resources Code §§ 7501-7609.

[2] (11849) 9 Stat. 352; Louisiana v. Garfield (1908) 211 U. S. 70, 76 held that this Act of 1849 was not repealed by the Act of 1850 next noted, the provisions of which applied to all states then in existence. See La Tere Co. v. Billiot's Shell Island (C. C. A. 5th 1939) 103 F. (2d) 53. The reason for Louisiana's receiving the first grant of this character is probably due to the vast areas of swamp and overflowed lands in that state.

[3] (1875) Rev. Stat. § 2479 *et seq.*, 43 U. S. C. § 982 *et seq.* (1946).

[4] Rice v. Sioux City R. R. Co. (1884) 110 U. S. 695, 698 decided that the Act of 1850 did not apply to then territories subsequently admitted as states. See also United States v. Minnesota (1926) 270 U. S. 181, 203.

[5] Culver v. Uthe (1890) 133 U. S. 655, 659.

[6] The Louisiana Act of March 2, 1849, designated the Secretary of the Treasury as the officer to carry out its provisions because the Department of the Interior was not created until the day following. Colby, *Mining Law in Recent Years*, Part II, (1948) 36 Calif. L. Rev. 355, 359.

Some idea of the importance of this ''swamp land'' grant may be obtained from the fact that lands of this character amounted to many millions of acres possessing extraordinary fertility due to the recurring deposits of enriching silt. In California alone there were nearly two million acres of swamp land, much of it lying in the delta region of the Sacramento and San Joaquin Rivers, lands which are now immensely productive as truck gardens and fruit orchards, unrivalled the world over.[8]

For the sake of brevity the Act was titled the ''Swamp Lands Act,'' and ''swamp and overflowed lands'' are commonly referred to by the courts as ''swamp lands.'' Judge Field stated that ''swamp lands'' as distinguished from ''overflowed'' lands may be considered as those that require drainage to fit them for cultivation; whereas ''overflowed'' lands are those which are subject to such periodical or frequent overflows as to require levees or embankments to keep out the water and render them suitable for cultivation.[9] This distinction is open to criticism because ''swamp'' lands also require levees and embankments to keep out the water after the land has been drained. The Supreme Court of the United States, in *Heath v. Wallace,*[10] said that whether ''swamp and overflowed lands'' should be taken as a general term or whether separable and referring to two different qualities of land was immaterial. ''Overflowed'' has reference to a permanent condition that will remain so without reclamation or drainage. Lands subject to temporary periodical overflow are not ''overflowed'' within the meaning of the Act. Otherwise, all lands which perchance might be overflowed at times of freshets and high waters but which for the greater portion of the year are dry lands would be included. This was manifestly not the intention of Congress. Lands subject to overflow by tides, the beds of rivers, lakes and other bodies of water are not swamp and overflowed lands.[11] The question is one of fact properly determinable by the Land Department, and while a grant is in the process of administration and until the legal title passes from the United States, an inquiry as to equitable rights comes within the cognizance of that department and not of the courts. Errors and mistakes in surveys are subject to correction.[12]

Time When Grant Took Effect

The first important question which arose was as to when the grant took effect. While the granting language of the act, that the lands ''shall be and are hereby granted,'' was unusually specific, nevertheless, the act also provided for issuance of patents by the United States to the respective states and stated that ''on that patent the fee simple title to said lands shall vest in the state.'' The inference was clear, therefore, that, prior to patent to the state, no fee simple title would pass, the title created being inchoate.[13] The courts have held, however, that the grant was one *in praesenti,* creating an immediate transfer of interest as of the date of the Act, September 28, 1850, to each state then in the union,[14] and that these areas thereupon ceased to be ''public lands.''[15] The grant operated on existing things and with reference to an existing state of facts. It was to take effect at once between an existing grantor and several separate and existing grantees.[16]

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[7] The legal subdivisions mentioned in the Act of 1850 are those made under the authority of Congress, the smallest of which are quarter-quarter sections or 40 acre lots. Robinson v. Forrest (1865) 29 Cal. 317, 325. If, without protection by levees, the greater part of the subdivision is unfit for cultivation in grain or other staple crops by reason of the overflow, it is regarded as swamp and overflowed. It is not enough that a crop of grass may spring up after the overflow subsides. Keeran v. Griffith (1866) 31 Cal. 461, 465.

[8] Wright v. Roseberry (1887) 121 U. S. 488, 496. Justice Field gives as a reason for the early reclaiming of these lands not only their extraordinary fertility, but also that they were the source of malarial fevers.

[9] San Francisco Sav. Union v. Irwin (C. C. D. Cal. 1886) 28 Fed. 708, 712, affirmed in Irwin v. Savings Union (1890) 136 U. S. 578.

[10] (1891) 138 U. S. 573, 584.

[11] Churchill Co. v. Kingsbury (1918) 178 Cal. 554, 174 Pac. 329.

[12] Heath v. Wallace, *supra* note 10 at 585; Oregon v. Hitchcock (1906) 202 U. S. 60, 70; Brown v. Hitchcock (1899) 173 U. S. 473, 476; Michigan Land Co. v. Rust (1897) 168 U. S. 589, 593, 596.

Therefore, as of the date of the act, the states received an inchoate title or present transfer, which did not depend upon the issuance of a patent by the United States.[17] This beneficial title lacked, however, the identification required to complete the title. When followed by issuance of a federal patent, the equitable title was converted into a legal or fee simple title. This latter title then related back to the date of the act and inured to the benefit of the state and its successors as of that date for all purposes.[18]

Identification of Lands Granted

Identification of these swamp lands became a matter of major importance. The Act of 1850 imposed the duty of making such identification on the Secretary of the Interior. He was instructed, as soon as practicable, to make lists and plats of such swamp lands and upon request to issue patents therefor. The act did not prescribe the manner in which the Secretary should discharge his duty nor the evidence required as to the character of the land. This was left to his discretion.[19] In administering the grant, the Secretary gave each state a choice between two elections: first, whether it would abide by the showing in the government surveyor's field notes; and, second, whether it would through its own agents make an examination in the field and present claims for lands believed to be swamp in character accompanied by proof of that fact. These elections by the state were generally respected and given effect. Where the election was to abide by the field notes, that, without more, was regarded a continuing selection of all lands shown by the plats and notes to be swamp in character. Where the other course was pursued, the presentation by the state of its claims with supporting proof was treated as a selection by the state.[20] The system of public land surveys was only being started in many of the western states. Since one of the tests imposed by the act as to whether land was swamp and overflowed was whether the greater part of any legal subdivision was ''wet and unfit for cultivation,'' it was essential that these swamp lands be officially surveyed in order to identify them.[21]

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[13] Little v. Williams (1913) 231 U. S. 335, 340.

[14] United States v. Minnesota, *supra* note 4 at 202; Work v. Louisiana (1925) 269 U. S. 250, 255; Little v. Williams, *supra* note 13; Michigan Land Co. v. Rust, *supra* note 12 at 591; Rogers Locomotive Works v. Emigrant Co. (1896) 164 U. S. 559, 570; Tubbs v. Wilhoit (1891) 138 U. S. 134, 137; Rice v. Sioux City R. R., *supra* note 4 at 698; French v. Fyan (1876) 93 U. S. 169, 170; United States v. Thibodeaux (C. C. A. 6th 1916) 232 Fed. 91, 95; Canal & Irrigation Co. v. Worswick (1922) 187 Cal. 674, 687, 203 Pac. 999, 1005; Foss v. Johnstone (1910) 158 Cal. 119, 110 Pac. 294; San Francisco Sav. Union v. Irwin, *supra* note 9.

[15] Wright v. Roseberry, supra note 8 at 502.

[16] Rice v. Sioux City R. R., *supra* note 4 at 698.

[17] In Little v. Williams, *supra* note 13 at 340, the court described this inchoate title as "a claim which was imperfect both at law and in equity."

[18] United States v. O'Donnell (1938) 303 U. S. 501, 509; Canal & Irrigation Co. v. Worswick, *supra* note 14 at 687, 203 Pac. at 1005.

[19] Michigan Land Co. v. Rust, *supra* note 12 at 601.

[20] United States v. Minnesota, *supra* note 4 at 211.

The Secretary's identification of the land as swamp land by making out the required list and official plat was held to be conclusive on collateral attack. But where he neglected or declared his inability to take such action, it was competent for the grantees of the state, in order to prevent their rights from being defeated, to identify the lands in any other appropriate way which would effect that object.[22] This burden of identifying swamp lands in the various states was so prodigious that the Secretary's office was literally ''swamped'' with applications and demands of the states. His office force was entirely inadequate to meet the emergency. As these lands were not withdrawn from sale until the filing in the local land office of the lists to be prepared by the Secretary of the Interior, they were assumed to be open to entry or location. It was only to be expected that in the interim they would be claimed and appropriated under other federal land laws. Conflicts inevitably arose between such claimants acting under federal laws and the states claiming the same lands as swamp lands. In the Land Department contests were permitted where claimants sought to prove that the lands were not swamp in character. These controversies increased between claimants making filings under United States laws and those claiming the lands as swamp lands, until contests pending before the Land Department were estimated to involve three million acres.[23] The legislatures of the various states affected very generally undertook to have these lands identified, to dispose of them and to authorize the issuance of state patents.[24]

The states and their swamp land grantees urged Congress to remedy this critical situation. On March 2, 1855,[25] an act was passed for the relief of purchasers of swamp lands which partially removed the embarrassment of the Land Department growing out of these controversies. The act directed the President to issue patents to federal applicants who had made entries of swamp lands in those cases where no patents had previously been issued to the states under the Act of 1850. Where any state had sold or disposed of such land prior to its entry under any of the other federal land laws, the President was not to issue patents to such entrymen until a release from the state had been first obtained. Where it was proved that any lands so purchased from the United States were actually swamp lands, the purchase money was either to be paid over to the state, or if the land had been located by scrip, land warrants, etc., the state was authorized to select in lieu an equal quantity of public land subject to entry. This statute was a plain recognition of the prior right of the states to swamp lands, since it provided that a United States patent could not be issued to any swamp land without a release by the state, and in the case of already completed purchases, the states were to be indemnified.[26]

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[21] Chapman & Dewey v. St. Francis (1914) 232 U. S. 186, 198; Kean v. Calumet Canal Co. (1903) 190 U. S. 452, 492. Unsurveyed lands are not public lands subject to selection. United States v. Northern Pacific Ry. (1940) 311 U. S. 317, 344.

[22] Wright v. Roseberry, *supra* note 8 at 509.

[23] Railroad Company v. Fremont County (U. S. 1869) 9 Wall. 89, 91.

[24] Tubbs v. Wilhoit, *supra* note 14 at 137; Emigrant Co. v. County of Wright (1877) 97 U. S. 339, 340.

[25] (1855) 10 Stat. 634.

Another curative act, dated March 3, 1857,[27] continued the Act of 1855 in force and extended it to all swamp land entries made since its passage.[28] This act confirmed selections which had been reported to the Commissioner of the General Land Office where the land had remained vacant and unappropriated and unclaimed by actual settlement under any federal law. The filing of a list of swamp lands in the General Land Office operated to perfect the title of the state to such lands. This title thereupon became superior to title under a patent issued subsequently by the United States. The approval of such swamp land selections and issue of patents therefore became, by virtue of the Act of 1857, merely ministerial with the Land Department having no discretion in the matter.[29]

An Act of March 12, 1860[30] extended the provisions of the swamp land grant to Minnesota and Oregon and recognized the right of states generally to provide for the identification of swamp lands without waiting for action by the Secretary of the Interior. It also placed a time limitation on the selection by the states of swamp lands then appearing as such on the public surveys and also on swamp lands thereafter surveyed after notice given by the Secretary of the approval of such surveys.[31]

These inconveniencies and conflicts of title were especially annoying and injurious to California. The great immigration to that state following the discovery of gold created a demand for lands easily reclaimed which possessed such extraordinary fertility.[32] Congress, on July 23, 1866, in order to clear up the confusion, enacted special remedial legislation for that state,[33] entitled ''An Act to Quiet Land Titles in California.''[34] This act dealt with various types of public land titles in California. Section 4 was devoted to swamp lands. It provided four methods to facilitate the identification of such lands:

> 1. It directed the Commissioner of the General Land Office, when government survey plats had already been approved, to certify to California as swamp and overflowed all lands represented as such on these official plats.
>
> 2. It directed the United States Surveyor General for California to examine the plats and surveys of swamp and overflowed lands made by the state. If he found them to conform to the United States surveys he was to make plats in conformity with such surveys and have them approved by the General Land Office.
>
> 3. Where the state and United States surveys were not found to conform and in cases where there were no surveys, then upon an application by the Governor of California, the Surveyor General was within one year directed to make segregation surveys of swamp lands according to the best evidence available.
>
> 4. If the state should claim as swamp land any lands not so represented on the United States plats and surveys, then the character of such claimed land as of September 28, 1950, was to be determined by the United

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[26] Tubbs v. Wilhoit, *supra* note 14 at 138; Wright v. Roseberry, *supra* note 8 at 509; Railroad Company v. Fremont Co., *supra* note 23.

[27] (1857) 11 Stat. 251; Martin v. Marks (1877) 97 U. S. 345, 347; Railroad Company v. Fremont County, *supra* note 23 at 92.

[28] Wright v. Roseberry, *supra* note 8 at 510.

[29] Martin v. Marks, *supra* note 27 at 347.

[30] (1860) 12 Stat. 3, as amended, 43 U. S. C. § 988 (1946).

[31] Wright v. Roseberry, *supra* note 8 at 511.

[32] Robinson v. Forrest, *supra* note 7 at 319.

[33] The act being remedial was to be strictly construed. Heath v. Wallace, *supra* note 10 at 580.

[34] (1866) 14 Stat. 218; Tubbs v. Wilhoit, *supra* note 14 at 137; Wright v. Roseberry, *supra* note 8 at 511.

States Surveyor General for California upon testimony taken before him, with his decision subject to approval by the General Land Office.

This Act of 1866 was intended to cure uncertainties, principally by recognizing the action already taken by California in identifying its swamp lands. The act superseded all previous rules and methods of identifying swamp lands in California and committed their identification and selection to other officers than the Secretary of the Interior, placing the burden of approval on the Commissioner of the General Land Office.[35]

The State of California early legislated on the subject of swamp lands.[36] This legislation was designed to facilitate the identification of these lands in cooperation with the federal government and to provide for their disposal. In 1861[37] the state established a Board of Swamp Land Commissioners and directed the county surveyors to make surveys and plats of such lands and to file these with the State Surveyor General, who was directed to compile and deliver to the Governor a general state map on which would be delineated all swamp lands claimed by California under the Act of 1850.[38]

The pioneer case decided by the Supreme Court of the United States under the Act of 1850 involved a subsequent railroad grant.[39] The court held that it was permissible to prove by oral testimony that the land in question was swamp land as described in the Act as of September 28, 1850. Identification by the Secretary of the Interior as required by the act was held not to be essential. Justice Clifford dissented on the ground that since the Swamp·Lands Act of 1850 prescribed identification by the Secretary of the Interior, oral testimony could not take the place of his determination. Later decisions have recognized the logic of this dissent and have held that parol evidence was inadmissible to prove that the lands were swamp in character in 1850. This is especially true where the Secretary of the Interior had decided they were not, and also, where federal patents had been issued, such patents not being subject to collateral attack.[40]

Administration of Act by the States

The cases herein cited indicate that when the various state legislatures enacted laws to carry into effect the provisions of the federal swamp land grant of 1850, as that act empowered them to do, they usually delegated the details of the administration of the grant to the counties in which the swamp lands were situated. The county surveyors were instructed to survey and prepare plats of the swamp lands in their respective counties for swamp land applicants and make these surveys available to the state and federal officials. The counties, acting through their boards of supervisors, were authorized to sell the swamp lands and enter into contracts of sale with individuals whereby such purchasers were to reclaim the lands and pay for them at prices that ranged from $1.00 to $1.25 per acre, usually spread over a period of years.[41] As might be expected, advantage was taken of a situation which opened the door to great possibilities for graft and imposition. Companies were formed which fraudulently obtained control of large acreages of swamp lands and speculated in their acquisition at grossly inadequate consideration and at the expense of the rights of the public.[42]

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[35] Heath v. Wallace, *supra* note 10 at 579 ; Tubbs v. Wilhoit, *supra* note 14 at 139 ; Wright v. Roseberry, *supra* note 8 at 512.

[36] Cal. Stats. 1855, p. 189 ; 1858, p. 198 ; 1859, p. 240. The Act of 1855 placed the state's swamp lands on sale for one dollar per acre. The applicant might take five years to complete the purchase price by paying ten per cent per annum in advance. He was required to reclaim one-half of the land within that period. The act limited each applicant to 320 acres. This was enlarged in 1859 to 640 acres. The applicant was required to have the tract surveyed by the County Surveyor and the plat and field notes were filed with the Surveyor General and the County Recorder. Swamp lands within specified distances of designated large cities and tide lands were excepted from sale.

[37] Cal. Stats. 1861, p. 355. The California legislation on this general subject is so great that anyone interested is referred to the CAL. POLITICAL CODE §§ 3440-3493 and CAL. PUB. RESOURCES CODE §§ 7601-7609. Also see, County of Kings v. County of Tulare (1898) 119 Cal. 509, 51 Pac. 866, where California's policy is considered and legislation noted.

[38] The case of Foss v. Johnstone, *supra* note 14 at 130 contains a resume of the federal and state legislation and a review of the principal cases (133-136). See also, Wright v. Roseberry, *supra* note 8.

[39] Hannibal R. R. v. Smith (U. S. 1869) 9 Wall. 95.

[40] McCormick v. Hayes (1895) 159 U. S. 332, 347 (all the prior cases were reviewed at 338-347) ; Chandler v. Calumet & Hecla Mining Co. (1893) 149 U. S. 79, 93 ; French v. Fyan, supra note 14 at 171 ; Niles v. Cedar Point Club (1899) 175 U. S. 300, 308 ; Ehrhardt v. Hogaboom (1885) 115 U. S. 67.

It was inevitable that sooner or later the question would be raised as to whether this immense grant of swamp lands, potentially of extraordinary fertility when reclaimed, was being properly administered in the interest of the public by the various states and their grantees. The Act of 1850 stated that the grant was made to enable the states "to construct the necessary levees and drains to reclaim the swamp and overflowed lands therein" and empowered the state legislatures to dispose of the lands; "*Provided, however,* that the proceeds of said lands . . . shall be applied exclusively, as far as necessary, to the purpose of reclaiming said lands by means of the levees and drains aforesaid."[43]

In an early case[44] the Supreme Court had said that the lands "were impressed with an important public trust." However, two years later,[45] the court modified this view by saying that at first it was of the view that an explicit and controlling trust had been created but that on mature reflection had decided otherwise. The security for the application of the proceeds to the object intended rested upon the good faith of each state. It was questionable whether a state could be called to account by the courts for any failure so to do. In the opinion of the court, Congress alone would seem to have the power to enforce the conditions. The court took this view largely because the proceeds derived from the sale of these lands were, by the terms of the act, to be applied to the work of reclamation only "as far as necessary" to attain the object. The court at a later date[46] said that private parties could not question the application of these proceeds to the building of levees and drains. Their disposal rested upon the good faith of the state, and the faithful performance of the duties imposed on the states was a matter between the two sovereign powers. It added that these swamp lands were of little value to the United States; whereas the states were concerned in their settlement and improvement, in the opening up of roads and other public works through them, in the promotion of the public health by systems of drainage and embankment, and were far more deeply interested in their disposal and management than was the United States. Still later the court said it was for the United States and not for the individual to complain of a breach of trust, if there be any, since the appropriation of the proceeds rested solely in the good faith of the state, there being no trust which followed the lands created by the statute.[47]

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[41] In Louisiana the selling price ranged from 10 cents to $5.00 per acre. Cross Lake Club v. Louisiana (1912) 224 U. S. 632, 635.

[42] Emigrant Company v. County of Wright, *supra* note 24 at 340. See also Emigrant Co. v. County of Adams (1879) 100 U. S. 61.

[43] (1850) 9 Stat. 519.

[44] Emigrant Co. v. County of Wright, *supra* note 24 at 342 ; see also Culver v. Uthe, *supra* note 5 at 659, where the court said the grant in the hands of the county was accompanied with a trust for the reclamation of the land.

[45] Emigrant Co. v. County of Adams, *supra* note 42 at 67.

[46] Mills County v. Railroad Companies (1882) 107 U. S. 557, 566.

Recent Decisions

Under the heading *Spanish and Mexican Grants,*[48] the case of *United States v. O'Donnell* was discussed.[49] Conflict between a Mexican grant and a swamp land title was there involved. The Mexican grant had been confirmed under the Mexican Claims Act. The United States had also issued a patent to California under the Swamp Lands Act. The court held that the Swamp Lands Act of 1850 was effective to transfer an interest in swamp lands only so far as they were then a part of the federal public domain and thus subject to the disposal of Congress. The Mexican grant in question antedated the Swamp Lands Act and was, therefore, superior to any rights claimed under the act. Even where the right of the state under the Swamp Lands Act is unqualified, the court said it was more accurate to say that the United States is no more than a donor granting without warranty those lands falling within the description and purview of the statute. The United States assumes no duty or obligations and gives no warranty of title to any grantee, thereby subjecting itself to any claims of equitable duty. Even if the lands in question had been sold to others, the United States was not accountable as a trustee, in spite of the issuance by it of the swamp land patent.[50] The court decided that the evidence established that the Mexican grant description of Mare Island included the swamp land described in the United States patent to the state and hence, because of priority of right, the Mexican grant title was superior.

A companion case, also involving Mare Island where the government's great naval base is situated, was decided some four years later.[51] It presented the same basic issues, involving the same Mexican grant of Mare Island and three other swamp land patents issued by the United States to the State of California. The United States contended that the description of Mare Island contained in the Mexican grant was broad enough to include the large acreage of swamp land adjoining the main island upland on the northwest and asserted that the *O'Donnell* case had virtually determined these issues in its favor. The swamp land owners did not contest the legal principles announced in that case, but their defense was factual, namely, that their swamp lands were not included in the description of the Mexican grant. The Supreme Court, reversing the Circuit Court of Appeals, sustained the trial court in its findings that the old maps, the facts surrounding the making of the grant and the subsequent history all proved that these swamp lands were never recognized as a part of Mare Island or "La Yegua", as it was named in the Mexican Grant.[52]

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[47] Hagar v. Reclamation District (1884) 111 U. S. 701, 712; see also Chandler v. Calumet Co., *supra* note 40.

[48] Colby, *op. cit. supra* note 6 at 370.

[49] (1938) 303 U. S. 501, 509.

[50] *Ibid.* at 515.

[51] Stewart v. United States (1942) 316 U. S. 354, *reversing* (1941) 121 F. (2d) 705 and *affirming* (1939) 29 F. Supp. 59. Title to these lands had already been held to have passed to California in San Francisco Savings Union v. Irwin, *supra* note 9.

Swamp Lands Containing Minerals

We have already noted[53] that when Judge Lindley wrote swamp and overflowed lands were not known to contain minerals, and that this afforded the most plausible explanation for his not having dealt with swamp lands. However, in more recent years, modern progress and discovery have brought to light valuable mineral occurrences in some of these areas. Low lying lands, bordering on streams which have their sources in gold bearing regions, have been proven valuable for gold dredging because of the fine particles of gold which have been carried down in suspension in the currents and deposited in these lands in valuable quantities. Also, great areas of marsh land have been found to contain natural gas and petroleum.[54]

The Land Department, following the passage of the Swamp Land Acts of 1849 and 1850, did not for many years have presented the question whether lands valuable for mineral were excepted from the swamp grants. It was not until phosphate was found in valuable quantities in swamp lands in Florida and immensely valuable deposits of petroleum were discovered in the swamp lands of Louisiana that the Department gave serious consideration to this problem. In the early part of this century, the federal government had been emphasizing the policy of conservation of natural resources. The executive branch had withdrawn lands of the public domain from entry which were deemed potentially valuable for the coal, oil, phosphate, potash, etc., which they contained. Congress had enacted legislation fortifying this executive action. The Supreme Court of the United States had decided that the withdrawals were constitutional.[55] It was but natural that the Land Department, the custodian of these lands, would carry this policy into effect to the best of its ability. It had already been successful in recovering for the United States title to oil lands in California and Wyoming of fabulous value. When it was called on to decide whether mineral lands were excepted from the swamp land grants, it issued "Instructions",[56] dated May 25, 1918, in answer to an inquiry from Louisiana. These "Instructions" reviewed at length the authorities and legislation on the subject and concluded that it had been the uniform policy of the government to reserve mineral lands from all classes of grants. Consequently, mineral lands were not included within the scope of the swamp land grants and could not lawfully be patented thereunder.

This ruling by the Land Department was repudiated by the leading case on this subject, involving swamp lands containing valuable petroleum deposits in Louisiana.[57] These lands had been included in a Petroleum Withdrawal made by Presidental order[58] and had been impressed with a *prima facie* mineral character by that withdrawal. The state was given an opportunity to show that the lands were not mineral bearing. When it failed to do so, the Land Department rejected the state's claim that the swamp land title was paramount.[59] The Supreme Court of the United States stated that neither the Swamp Land Act of 1849, which affected Louisiana exclusively, nor the general Act of 1850 contained any exception or reservation of mineral lands. In 1849 and 1850 there was no settled policy on the part of the United States of withholding mineral lands from disposal, save under laws specially excluding them. The court noted that the day before Congress had approved the Swamp Land Act of 1850, it had provided for the disposal of public lands in the Territory of Oregon to settlers and expressly excepted ''mineral lands.''[60] It concluded, however, that this was insufficient to establish a settled public policy in reference to the reservation of mineral lands. Congress having had before it the day preceding the subject of excluding mineral lands from other grants, it followed that, since it did not specifically except them from the grant of swamp lands to the several states, that fact ''indicates that no reservation of such lands was intended.'' The court went on to say that, since there was at that time no settled policy of reserving mineral lands, there was no substantial ground for reading such a reservation into the broad and unrestricted grants of swamp and overflowed lands to the states. Such lands were not then generally known to contain valuable minerals, but were thought valuable, only after reclamation, for agricultural use, which was the purpose of the swamp land grants. Especially was this true where the discovery of oil and gas in the lands in question had been made at a much later date. The court differentiated its later decisions relating to school lands[61] where it had held that the Act of 1853 granting school lands to California was not intended to cover mineral lands, by noting that,

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[52] Stewart v. United States, *supra* note 51 at 356. The government had contended that there was a continuous unbroken neck of upland connecting Mare Island with the marsh land and that, therefore, the marsh land constituted a peninsula which could not be divorced from the island proper. The Supreme Court held that even if this were the fact, it would not affect the result for, "It is common knowledge that lands not in fact surrounded by water are sometimes called islands." Note, p. 362.

[53] *Supra* note 1.

[54] Natural gas has been held to be a mineral within the meaning of the mining laws. Colby, *The Law of Oil and Gas* (1942) 30 CALIF. L. REV. 245, 250. Much of the natural gas which now supplies San Francisco comes from lands bordering the lower reaches of the two great rivers of Central California and some of this gas producing land is "swamp and overflowed." Immensely valuable deposits of petroleum have in recent years been developed in the swamp lands of Louisiana.

[55] Colby, *op. cit. supra* note 54 at 254.

[56] Swamp Land Grants and Mineral Lands (1918) 46 Land Dec. 389.

> "the discovery in 1849 that California was rich in precious metals, bringing its mineral lands to the attention of Congress, had led to the adoption in reference to that State of a local policy, plainly manifested in other provisions of the Act, making specific exceptions of mineral lands, by which, unlike the ordinary laws for disposing of public lands in agricultural States, the mineral lands of that State were uniformly reserved from sale, preemption and grants for public purposes."[62]

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[57] Work v. Louisiana, *supra* note 14. This case was considered in the second article of this series but its importance merits a reconsideration in this connection. Fall v. Louisiana (1923) 53 App. D. C. 22, 287 Fed. 999 was modified and affirmed by the Supreme Court. This suit was brought in behalf of the federal government. Work being then and Fall before him Secretaries of the Interior.

[58] For a discussion of these withdrawals and their validity, see Colby, *op. cit. supra* note 54 at 254.

[59] State of Louisiana (1921) 48 Land Dec. 201, 203. On petition for rehearing, the department held that since mineral lands were not expressly included within the terms of the swamp land grants of 1849 and 1850, they did not inure to the state and that until the Secretary's approval under the Act of 1849 or date of issuance of patent under the Act of 1850, the mineral or non-mineral character of land claimed as swamp was open for investigation and adjudication. The Land Department in (1920) 47 Land Dec. 366 had already decided that these same lands if mineral in character were not included in the swamp land grant. Still earlier in State of Florida (1919) 47 Land Dec. 92, it had held that until patented the Land Department had jurisdiction to investigate and determine both the swamp and overflowed character and the mineral character of any land claimed under the swamp act. In the Florida case, swamp land valuable for phosphate was involved. Following the adverse decision of the Supreme Court, the Land Department reconsidered and overruled its earlier decisions above noted in both the Louisiana and Florida cases. State of Louisiana (1925) 51 Land Dec. 291, 292.

[60] Act of September 27, 1850; 9 Stat. 496.

[61] Mining Co. v. Consolidated M. Co. (1880) 102 U. S. 167; Mullan v. United States (1886) 118 U. S. 271; United States v. Sweet (1918) 245 U. S. 563.

[62] Work v. Louisiana, *supra* note 14 at 258.

The court noted that it was not until 1917 that the Land Department had departed from its earlier construction of these swamp land grants, and had first held that mineral lands were to be excepted. It concluded that the Swamp Land Acts granted to the states the swamp and overflowed lands without reference to their mineral character.[63] This decision is unique in the fact that it is the outstanding exception to an almost uniform line of cases involving railroad grants,[64] state school grants,[65] and placer locations made under the general mining laws[66] where the federal government's right to retain valuable petroleum lands has been upheld.

While the language above quoted could be used as an argument that, as to California, known in 1849 to be "rich in precious metals," a different conclusion might have been reached, especially in view of the later remark of the court, that this had "led to the adoption in reference to that state of a local policy . . . by which . . . the mineral lands of that state were uniformly reserved from sale, preemption and grants for public purposes." Nevertheless, the unrestricted conclusion of the court, "that the swamp land acts granted to the states the swamp and overflowed lands . . . without reference to their mineral character," is broad enough to include California and all the states which were in 1850 qualified to receive these swamp lands.[67]

The Land Department was later on called on to decide whether swamp land selections made by Oregon, which had possibilities of mineral value, were patentable as swamp land. Oregon and Minnesota occupied a different status with respect to their swamp lands. It was not until March 12, 1860,[68] that Congress extended the provisions of the Swamp Lands Act of 1850 to those states. The Land Department in its decision issued in the form of Instructions[69] noted that the Oregon so-called donation act[70] of September 27, 1850, excepted mineral lands from its grant and also that the Supreme Court of Oregon[71] had decided that the Oregon Swamp Land Act of 1860 was a limited and conditional grant only of such lands as the federal government had not already reserved, sold or disposed of prior to confirmation of title and concluded. As a consequence, mineral lands in Oregon were effectively reserved, so that the swamp grant could not be applied to them. In Minnesota this question would not be material, because the mining laws are not applicable to that state.[72]

GRANTS TO RAILROADS.[73] THE POLICY OF CONGRESS IN MAKING THESE GRANTS AND THEIR EXTENT

Beginning with 1850 Congress embarked on a policy of subsidizing railroad construction by lavish grants from the public domain. These grants totalled upwards of 150,000,000 acres. Some 100,000,000 acres of this total was in the ''precious metal'' or ''mining'' states of the West,[74] the latter being mainly grants to proposed transcontinental railroads and their branches. The largest of these involved an estimated 40,000,000 acres,[75] which Justice Field described as an ''immense territory'' 2,000 miles in length and 40 miles in width, making an area nearly equal in extent to that of Ohio and New York combined and covering 80,000 square miles.[76]

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[63] *Ibid.* at 259.

[64] United States v. Southern Pac. Co. (1919) 251 U. S. 1.

[65] West v. Standard Oil Co. (1929) 278 U. S. 200.

[66] United States v. Midwest Oil Co. (1915) 236 U. S. 459.

[67] This is the view taken by the Land Department in its comment on the effect of the Work v. Louisiana decision by the Supreme Court, (1925) 51 Land Dec. 292, 317.

[68] (1860) 12 Stat. 3.

[69] (January 15, 1926) 51 Land Dec. 316.

[70] (1850) 9 Stat. 496.

[71] Morrow v. Warner Valley Stock Co. (1909) 56 Ore. 312, 101 Pac. 171.

[72] *Supra* note 69 at 317.

[73] This subject is treated in LINDLEY, MINES §§ 149-162. See also 43 U. S. C. §§ 981-94 (1946).

By 1870 this liberal policy had met with great public disfavor, so much so, that in 1872 the House of Representatives adopted a resolution condemning these subsidies, advocating their discontinuance and stating that the public lands should be reserved for actual settlers and to foster educational purposes.[77] After 1871 such grants were discontinued. Much has been written in criticism of the congressional policy in making these grants,[78] but there is much to be said for as well as against. Justice Van Devanter, commenting on the grant to the Northern Pacific Railway Company[79] to bring about the construction and operation of a 2,000 mile transcontinental line extending from Lake Superior to Puget Sound and Portland, called attention to the fact that at the date of the grant this intervening area,

> . . . consisted of great stretches of homeless prairies, trackless forests and unexplored mountains,

and that the purpose of the grant was,

> . . . to facilitate the development of that region, promote commerce, and establish a convenient highway for the transportation of mails, troops, munitions and public stores to and from the Pacific coast, with all the resultant advantages to the Government and the public.

Justice McKenna in an earlier case[80] said,

> They were given as aids to enterprises of great magnitude and uncertain success and which might not have succeeded under a restricted and qualified aid.

Referring specifically to the grant there in question, he added,

> We shall be led into error if we conclude that because the railroad is attained it was from the beginning an assured success . . . the aid to the company was part of the national purpose, which this court has said induced the grants to the transcontinental railroads. . . . And we may say that the policy was justified by success. Empire was given a path westward and prosperous commonwealths took the place of a wilderness.

When one takes into consideration the enormous expense of building these transcontinental railroads, the then seemingly insurmountable problems of engineering to overcome, the difficulties of financing what were at that time considered extremely hazardous ventures, and also recalls that in some instances receiverships and reorganizations of the grantee railroads ensued,[81] he will realize that Congress, looking at the picture as it appeared when the earlier grants were made, was justified in its liberality. These grants were ''the product of a period'' in our national history. Later on when fortune had favored some of these risky undertakings and the tremendous development of the lands which the roads had opened up had taken place the scene changed. Some of the railroads eventually prospered beyond all anticipation, and hence, the revulsion of feeling.

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[74] LINDLEY, *op. cit. supra* note 73 at § 149.
[75] Great Northern Ry. v. U. S. (1942) 315 U. S. 262, 273.
[76] Barden v. Northern Pac. R. R. (1894) 154 U. S. 288, 313, 331.
[77] Great Northern Ry. v. U. S., *supra* note 75 at 273.
[78] See *Land Grants,* 9 ENCYC. OF SOCIAL SCIENCES 35 (1933) ; *Land Grants to Railways,* 3 DICTIONARY OF AMERICAN HISTORY 237 (1940).
[79] United States v. Northern Pac. Ry. (1921) 256 U. S. 51, 63.
[80] Oregon and Cal. R. R. v. United States (1915) 238 U. S. 393, 416, *reversing* (1911) 186 Fed. 861.
[81] *Id.* 407, 435 ; U. S. v. Northern Pac. Ry. (1940) 311 U. S. 317, 326, 340.

In the early days, from 1850 to 1862, the railroad grants were made directly to the states, largely in the Middle West, which acted as trustees for the benefit of the companies constructing the railroads, and the responsibility of administering the grants was placed on these states. Beginning with July 1, 1862, when the Pacific railroad grant was made,[82] this policy was altered, because the transcontinental railroads then projected were to pass through many states and territory remote from state control, and state control would have been confusing and conflicting. Thereafter the grants were made directly to the respective railroad companies.

The customary grants were of the odd numbered sections of public land existing within ten mile strips on both sides of the line of the road. These were called ''primary limits'' and the lands granted ''place lands.'' Lands in these odd numbered sections which were already reserved, granted, appropriated, pre-empted, homesteaded or subject to other claims and rights at the date of definite location of the road were excepted and were termed ''land lost to the grant.''[83] In order to compensate the companies for these losses, they were given the right to select in lieu thereof odd numbered sections not more than 10 miles beyond the ''place lands'' on each side of the right of way in two additional strips referred to as ''first indemnity belts'' or ''first indemnity limits.'' In some cases where the lands in these belts had already been largely claimed by settlers and others, these first indemnity limits were extended out 10 miles still further to form ''second indemnity limits.'' Mineral lands were, as a recognized policy of Congress, specifically excluded from these railroad grants, and in lieu thereof, in some instances, the selection of agricultural lands within 50 miles on each side of the right of way in what were known as ''mineral indemnity belts'' was authorized.[84] In exceptional instances the railroads were aided by bonds issued by the United States.[85]

These railroad grants were not gifts.[86] Although they granted rights they also imposed obligations.[87] Instead of giving a gratuitous reward for something already done, these grants were a proposal to the grantees to the effect that if the latter would locate, construct and put into operation designated lines of railroads, patents would be issued to the companies confirming to them title to the public lands granted. The proposal could be accepted or rejected. If accepted, the parties were brought into such contractual relations that the terms of the proposal became obligatory on both. By constructing the roads at enormous cost and putting them into operation, the companies performed their part of the contract and became entitled to performance by the Government. They thereby earned the right to the lands specified.[88]

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[82] (1862) 12 Stats. 489.

[83] United States v. Northern Pac. Ry., *supra* note 81 at 328; U. S. v. New Orleans Pac. Ry. (1919) 248 U. S. 507; Endenborn v. United States (C. C. A. 5th 1925) 5 F. (2d) 814; McNary Lumber Co. v. United States (C. C. A. 5th 1925) 6 F. (2d) 864, 865; Gallup v. Northern Pac. Ry. (D. Wash, 1924) 295 Fed. 326.

[84] United States v. Northern Pac. Ry., *supra* note 81 at 328.

[85] Barden v. Northern Pac. R. R., *supra* note 76 at 333.

[86] Burke v. Southern Pacific Co. (1914) 234 U. S. 669, 679.

[87] Oregon and California R. R. v. United States, *supra* note 80 at 435.

In construing these grants all ambiguities are resolved in favor of the sovereign grantor.[89]

Congress had two major purposes in view in making these grants. The primary purpose was to provide the sinews of finance and thus aid the railroads in raising the funds essential for such costly construction; and the secondary purpose, which was inaugurated after the early grants had been made, was "to people the country" by encouraging settlers to acquire and establish homes on the public domain through which the railroads extended.[90] Consequently, these acts or the amendments thereto usually specifically provided that the odd-numbered sections granted to the railroads should be sold to actual settlers only, in quantities not exceeding 160 acres to one purchaser and for a price not exceeding $2.50 per acre.[91]

As the country developed, these railroad lands increased so greatly in value that the grantee railroads were charged with perverting the "bounty of Congress" by ignoring the actual settler and enriching "a few financial adventurers"; that these

> lands granted for national purposes were disposed of in large blocks to speculators as well as to development companies organized by officers of the railroad companies.[92]

In consequence of a memorial presented to it, Congress on April 30, 1908, adopted a joint resolution authorizing the Attorney General to bring suit to enforce the provisions of certain grants for the construction of a railroad from California to Portland, Oregon.[93] Suit was brought, and the proof established the fact that the company had made sales of thousands of acres in single blocks to individuals who were not actual settlers and for prices ranging from $5.00 to $40.00 an acre and subsequently had even withdrawn from sale altogether all of its remaining unsold lands, asserting that they were mainly timberlands and unfit for settlement. However, it was also proved that several thousand persons had made application to purchase some of the lands for settlement purposes and been refused. In answer to the company's contention that the unsold lands were timberlands and unfit for settlement, the court said that whatever the difficulties of performance, relief might have been secured through an appeal to Congress.

Over 3,000,000 acres of land had inured to the Oregon and California Railroad Company under the original grants. By reason of its violation of the covenants to sell to actual settlers at the price fixed by the granting acts, it was held to have forfeited its right to over 2,300,000 acres which were still unsold, having a value in excess of $30,000,000. Congress having initiated this litigation, the court left it "for Congress to provide by legislation for their disposition in accordance with such policy as it may deem fitting." Congress by Act of June 9, 1916,[94] declared revested in the United States all railroad lands which had not been sold prior to July 1, 1913. The act also provided that an accounting should be had and the railroad company credited with $2.50 per acre for the entire acreage originally granted, and from this total sum should be deducted the amounts received by the company from its sales of lands.[95]

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[88] Burke v. Southern Pacific R. R., *supra* note 86 at 680; United States v. Northern Pacific Ry., *supra* note 79 at 64.

[89] Great Northern Ry. v. United States, *supra* note 75 at 272; Burke v. Southern Pac., *supra* note 86 at 680.

[90] Oregon and Cal. R. R. v. U. S., *supra* note 80 at 414; Southern Oregon Co. v. U. S. (C. C. A. 9th 1917) 241 Fed. 16, 21.

[91] Oregon and Cal. R. R. v. U. S., *supra* note 80 at 396, 413, 434.

[92] *Id.* at 408, 436. *See* Southern Oregon Co. v. U. S., *supra* note 90.

[93] Oregon and Cal. R. R. v. U. S., *supra* note 80 at 409, 438.

[94] (1916) 39 Stat. 218.

Where a railroad grant conflicted with an Indian Reservation, it was held that even though an erroneous survey made by the Land Department had shown the lands to be outside the reservation and the railroad had sold such lands to purchasers in good faith, nevertheless, they were not bona fide purchasers under the public land laws and the Indian rights were superior.[96] Lands in actual occupancy of Indians were held excluded from railroad grants even though patented to the railroad. The patents were cancelled to the extent of such occupancy. The policy of the government from the beginning has been to respect the Indians' right of occupancy, individual as well as tribal. It is not necessary that it be recognized by statute or other formal governmental action. It flows from a settled governmental policy.[97] Occupancy necessary to establish aboriginal possession is a question of fact.[98]

Time When the Grants Take Effect

Practically all of these several railroad grants have been held to be grants *in praesenti,* as far as ''place lands'' are concerned.[99] This is in the sense that title to the granted land, when identified, relates back to the date of the granting act.[100] We have seen that land grants to the states for educational purposes[101] and swamp land grants, where the lands granted have already been surveyed, are grants *in praesenti.* There is one distinction, however, for in the case of both swamp and school land grants, the lands already surveyed are at that time definitely ascertainable and identifiable; whereas, in the case of railroads, the lands granted are called ''floats'' because they are unidentifiable and indeterminate in position until the line of the railroad has been definitely located and established.[102] Once the line has been definitely located and the map of definite location filed, the odd-numbered sections to which the railroad is entitled are identifiable and all that remains is to determine whether excepted rights have attached or whether these sections are known mineral lands. Naturally the title to indemnity land does not attach until the indemnity selection has been made. Until then the right continues to be a ''float.'' There is also one other material distinction in the case of railroad grants. This arises from the explicit exception ''of mineral lands'' from those grants. We shall see when we discuss this phase of the subject that the courts have held that this question of mineral character may be inquired into up to the date of the patent to the railroad. The doctrine of relation may not be invoked to carry the railroad title back to the date of the grant and defeat subsequently initiated mineral rights.[103]

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[95] U. S. v. Oregon and Cal. R. R. (D. Ore. 1925) 8 F. (2d) 645, 661. The total amount due the railroad company from the government under the accounting was found to be nearly one and three quarter million dollars, but the unsold lands forfeited by the company to the United States amounted to over 2,000,000 acres valued at $30,000,000, most of which became a part of the National Forests in Oregon. Also see, Southern Oregon Co. v. United States, *supra* note 18, which applied the same principles to the grant there under consideration.

[96] Northern Pac. Ry. v. United States (1913) 227 U. S. 355, 367, *affirming* (C. C. A. 9th 1911) 191 Fed. 947.

[97] Cramer v. United States (1923) 261 U. S. 219, 227, *reversing* (C. C. A. 9th 1921) 276 Fed. 78.

[98] U. S. v. Santa Fe Pacific R. R. (1941) 314 U. S. 339, 345.

[99] U. S. v. Northern Pac. Ry., *supra* note 79 at 328. U. S. v. Oregon & Cal. R. R., *supra* note 95 at 651.

[100] Burke v. Southern Pac. Co., *supra* note 86 at 685.

[101] Colby, *Mining Law in Recent Years,* Part II, (1948) 36 CALIF. L. REV. 355, 378.

[102] Hannibal R. R. v. Smith (U. S. 1869) 9 Wall. 95, 97; Barden v. Northern Pac. R. R., *supra* note 76 at 313.

Grants of Rights of Way

In addition to the grants of odd-numbered sections and as a further incentive ''to encourage development of the Western vastnesses,'' Congress, of necessity, had to grant rights to lay track across the public domain. Such rights could not be secured against the sovereign by eminent domain proceedings or adverse user. For a time special acts were passed granting to the designated railroads ''the right of way'' through the public lands. However, the burden of enacting this special legislation for each railroad moved Congress to adopt a general right of way statute, Act of March 3, 1875.[104] Judge Lindley has pointed out the fact that under the terms of this act the railroad acquired only a ''limited fee''[105] to the right of way granted. The railroad could not alienate the right of way lands or use them except for railroad operation and acquired no title to the underlying minerals.[106] His conclusions are confirmed by the recent case of *Great Northern Ry. v. United States.*[107] That case presented the question as to whether the railroad company had any right to the oil and minerals underlying its right of way acquired under the general right of way statute of 1875. Congress had passed the Act of May 21, 1930,[108] providing for the leasing of the right to extract oil from railroad rights of way. No lease under the act had been issued to the railroad company. The suit was brought by the federal government to enjoin the railroad company from drilling for oil and gas.

The court first considered the nature of the right granted by the right of way Act of 1875 and concluded that it ''clearly grants only an easement, and not a fee.'' The right granted is one of ''use and occupancy only, rather than the land itself.'' The court distinguished certain of its earlier decisions,[109] where the right of way granted was described as ''a limited fee,'' by noting that this conclusion and description of the nature of the right granted was based on cases arising under specific land grant acts passed prior to 1871, where rights of way were included with the grants of the odd-numbered sections, and that Congress' change of policy after 1871 was not brought to the court's attention in these earlier cases. The decision reviews exhaustively the Congressional history and the contemporaneous administrative interpretation of the Act of 1875. The court concluded that since the railroad's right of way was but an easement, it had no right to the underlying oil and minerals.

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[103] The Land Department may inquire into and determine the character of the land at any time prior to patent. Northern Pac. Ry. (1937) 56 Land Dec. 201, 203.

[104] (1875) 18 Stat. 482; 43 U. S. C. 934 (1946).

[105] Sometimes also referred to as a "base" or "qualified" fee.

[106] LINDLEY, MINES § 153.

[107] *Supra* note 75. Also see Opinion of Land Department, (1937) 56 Land Dec. 206.

[108] (1930) 46 Stat. 373; 30 U. S. C. 301 (1946). Regulations for leasing right of way for the extraction of oil and gas (1930) 53 Land Dec. 137. Also see (1931) 53 Land Dec. 339.

[109] Northern Pacific Ry. v. Townsend (1903) 190 U. S. 267, 271; Rio Grande Ry. v. Stringham (1915) 239 U. S. 44, 47.

However, the court said that this result did not "freeze the oil and minerals in place," for the railroad company would be free to develop them under a lease executed pursuant to the Act of 1930, above noted.[110]

Where a forest reserve (now called a National Forest) had been created, a railroad company could not acquire a right of way through the reserve under the Act of 1875, which expressly excepts lands specially reserved from sale from its operation, even though before the reserve was created, but after its temporary withdrawal, the railroad had taken steps preliminary to construction. Railroad rights of way through forest reserves can only be secured through application to the Land Department when, in the judgment of the Secretary of the Interior, concurred in by the Secretary of Agriculture, the public interests will not be injuriously affected.[111]

Indian reservations, unless there is specific legislation to the contrary, are generally treated as public lands subject to railroad right of way. These right of way grants are not regarded as bestowing a bounty on the railroads, but stand upon a somewhat different footing from private grants and receive a liberal construction favorable to the purposes in view.[112]

Since the railroad rights of way are only easements, no prescriptive rights are obtainable by third parties of any portions of such right of way strips.[113] It is suggested, however, that such a prescriptive right might be acquired if there is an abandonment of the right of way, but this is dependent upon the intention.[114]

Grants of Indemnity Lands[115]

It was obvious from the outset that in innumerable instances the odd-numbered sections within the place or primary limits of the various railroad grants would, at the time of filing the map of definite location of the railroad, have become subject to other valid claims. Many of these sections might also be mineral in character. Since the railroad grant acts expressly excepted mineral lands and prior valid non-mineral claims from their operation, it was recognized that great losses of these odd-numbered sections within 10 miles of the line would be sustained by the grantee railroads unless some form of compensation were provided to make up for these deficiencies.[116] Congress anticipated this situation and, as we have noted, provided "indemnity limits" or strips extending parallel to and on each side of the right of way, usually for another 10 miles in width beyond the place limits and in some cases this distance was doubled to create "second indemnity limits." Within these additional areas the railroads were authorized to select an equal acreage of "agricultural" land to make up for their "place land" losses.[117] The place lands became fixed and identifiable and were no longer "floats" as soon as the railroad right of way had been surveyed and the map of definite location filed. Title to the odd-numbered sections in the place limits, that were not excepted for one reason or another, then vested in the railroad and related back to the date of the granting act. The titles to the indemnity lands, however, only became fixed and were no longer "floats", as of the date of each indemnity selection by the railroad. When it could be established that any place or base lands were not available because of a prior claim or because of their mineral character, and the company had made a selection of an equal area of land within the indemnity limits in lieu of its loss of place lands, its title to such indemnity selections attached. The Land Department thereafter could only check and see that the legal requirements existed. It could not, nor could Congress, suspend or defeat the title once attached.[118]

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[110] Great Northern Ry. v. U. S., *supra* note 75 at 279; MacDonald v. United States (C. C. A. 9th 1941) 119 F. (2d) 821 was affirmed with modification.

[111] Chicago, Mil. & St. P. Ry. v. United States (1917) 244 U. S. 351, 357, *affirming* (C. C. A. 9th 1914) 218 Fed. 288. See 30 Stat. 1233 (1899); 43 U. S. C. 958 (1946).

[112] Nadeau v. Union Pacific R. R. (1920) 253 U. S. 442, 444.

[113] Montgomery v. Atchison T. & S. F. Ry. (C. C. A. 10th 1937) 89 F. (2d) 94, 97; Barnes v. Southern Pac. Co. (C. C. A. 9th 1926) 16 F. (2d) 100, 102, 104.

[114] Barnes v. Southern Pac. Co. (C. C. A. 9th 1924) 300 Fed. 481, 483. See also Stuart v. Union Pac. R. R. (1913) 227 U. S. 342, 353, *affirming* (C. C. A. 8th 1910) 178 Fed. 753.

[115] LINDLEY, MINES § 157.

[116] These excepted lands were called "losses" or "bases for indemnity," Southern Pacific R. R. v. Fall (1922) 257 U. S. 460, 461.

[117] These were called "indemnity lands" or "lieu selections."

A suit of unusual interest, called the *Forest Reserve Case,*[119] was brought by the United States to cancel patents allegedly erroneously issued to the Northern Pacific Railway Company for indemnity lands. The losses of place lands sustained by the company had amounted to over 4,000,000 acres. It was claimed that the lands available for indemnity were insufficient to supply the losses. A temporary executive withdrawal of these lands for forest reservation purposes had been made prior to their selection by the company, but in issuing the patents the Land Department had overlooked this fact. The question was, when the losses exceeded the land available for indemnity, whether there was any need for selection by the company under such circumstances and whether the United States could reserve or appropriate to its own use lands in the indemnity limits required to supply losses in the place limits. The court decided that such reservation by the United States could not lawfully be made under such circumstances. The indemnity provision in the granting act confers a "substantial right" on the railroad which "cannot be thus cut down or extinguished." The court added that if the government could take part of the lands required for indemnity purposes, it could take all and thereby entirely defeat the provision for indemnity.[120] The case was remanded to have the question of asserted deficiency determined by the Land Department as of the date of the temporary withdrawal.

The Forester of the Department of Agriculture, which had charge of the forest reserves, could not agree with the Department of the Interior's Land Department and raised objections to a proposed adjustment. As a result, Congress passed a Joint Resolution on June 5, 1924,[121] directing the Secretary of the Interior to withhold action in the matter until the situation had been investigated by Congress. The result was an investigation followed by the Act of June 25, 1929,[122] which declared forfeited certain of the railroad company's rights and directed that a suit be brought to adjust the grant but provided that the company should be compensated for any lands to which the courts might find the company entitled. As a result of the suit, the trial court found the company entitled to patents for certain lands and awarded compensation for 1,453,061 acres of land situated within the newly created forest reserves. March 22, 1936,[123] Congress, in order to expedite the final determination of the case, authorized a direct appeal to the Supreme Court of the United States. On this appeal,[124] the government urged various breaches of covenant by the company (335-342, 369-370). The justices were equally divided on this question of forfeiture. No decision was reached because their rulings on other issues disposed of the controversy.[125]

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[118] United States v. Work (App. D. C. 1925) 4 F. (2d) 172, 173, held that the Secretary of the Interior had no discretion even pending valuation of the selected land.
[119] United States v. Northern Pacific Ry., *supra* note 79; *reversing* (C. C. A. 9th 1920) 264 Fed. 898.
[120] United States v. Northern Pacific Ry., *supra* note 79 at 67.
[121] (1924) 43 Stat. 461.
[122] (1929) 46 Stat. 41; 43 U. S. C. 921 (1946).

One of the main issues was as to the meaning of the phrase ''agricultural lands.'' There were nearly two million acres of losses by reason of the fact that the base or place lands had been returned as mineral in character. In considering this question, the court held that the words ''mineral'' and ''agricultural'' as used in the Railroad Act were not to be read strictly as defined by the dictionary. Mineral lands embrace deposits valuable for marble, slate, petroleum, asphaltum, and even guano, which are not so defined in lexicons. Likewise, filings on ''agricultural'' lands mentioned in acts of Congress have been allowed on forest and grazing land and, in fact, all types of land which in good faith were sought for a home, provided the settler could make them habitable. This has been true, in spite of the fact that the applicable acts of Congress require ''cultivation'' as a prerequisite to acquisition of title. While lands containing timber have been taken up for homes, a certain portion of the lands had to be cleared for cultivation. Lands valuable for timber or stone or other use, which could not be cultivated or farmed when cleared, could not be so taken up. By the use of the word ''agricultural'' and the right to select lieu lands anywhere along the line, Congress intended to give the company the privilege of selecting more valuable lands than the wild forest non-mineral lands contiguous to the mineral lands within the place limits in the mountain regions, which non-mineral lands were of little or no value and practically unusable. By the use of the word ''agricultural'', the company was precluded from selecting other mineral lands in lieu of mineral lands lost in the place limits. The court considered that the word ''agricultural'' was not intended to be synonymous with ''non-mineral'', but as synonymous with ''land subject to be taken up by pre-emptors and homesteaders under the public land laws.'' (361-363.) The court concluded that land in the forest reserves valuable solely for timber and other uses which did not justify pre-emption or homestead settlement was not selectable by the company as indemnity. Such selections must be confined to land that was susceptible of clearing and subsequent cultivation or for grazing or of similar homestead character (364). The court further held that, if the government's act of withdrawal of lands for forest reservation purposes from the indemnity limits left insufficient vacant land available for selection, the company had the right to select from the withdrawn lands (365). Even the subsequent restoration to the public domain of the withdrawn lands in amount sufficient to make up the deficiency created by the original withdrawal would not defeat the company's right to compensation under the Act of Congress, for the withdrawals were unauthorized as far as the company was concerned (366). The company was not called on in making the money settlement by way of compensation for land "losses", to account for moneys received by it for certain of the lands sold by it for higher prices, as was required in the *Oregon and California Railroad* case, because the Congressional requirement that the lands be opened to settlement in the latter case did not apply to the lands here in question (368).[126]

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[123] (1936) 49 Stat. 1369.

[124] U. S. v. Northern Pacific Ry., *supra* note 81.

[125] Some of these rulings were that, while as to unsurveyed lands within the withdrawn forest reserve area, no odd-numbered sections could exist, unsurveyed lands not being public lands (344), nevertheless, the company had the privilege of selection when they were surveyed, notwithstanding the withdrawals (347), that conflicting Indian reservations did not operate to defeat the right of indemnity selection (349); that the company did not, as charged by the government, adopt a more circuitous route for its line in order to obtain additional lands (352); that as to certain lands alleged to have been fraudulently classified as mineral, thus giving the company additional indemnity selection, the case was to go back for a trial of the fraud issue (358).

The creation of various other federal land reserves also created some serious problems for the railroads. An indemnity railroad selection had been filed and completed in all respects. It was cancelled because of a subsequent temporary executive withdrawal for a water power site. Suit was brought to enjoin the Secretary.[127] The court held that the filing of a railroad indemnity selection was not an initial step but rather the concluding step of one who by full compliance with the law has earned the right to receive title. The ultimate obligation of the government with respect to indemnity lands was similar to that respecting lands in place. The only difference was in the mode of identification. Those in place are identified by filing the map of definite location, and the indemnity lands by filing selections in lieu of losses in the place limits. The Secretary had no discretion to enlarge or curtail the rights of the railroad. Upon its full compliance with the selection requisites, it became the equitable owner of the land in question (236-239).

The question whether lands are swamp lands or previously occupied and appropriated so as not to be properly subject to railroad indemnity selection is expressly committed to the Land Department.[128]

Congress did not intend that coal lands should be acquired as indemnity lands. It has been the uniform practice of the Land Department to confine railroad lieu selections to lands not known to contain coal, iron, or other minerals.[129] However, where the granting act expressly provided that lands "of equal quality" might be selected, the railroad had the right to select coal lands in lieu of coal lands. It was held that the Secretary of the Interior must determine the equality in value as provided by the act according to the conditions existing at the time the selection was made and could not take into consideration subsequently discovered facts as to value.[130]

Indemnity selections must be for units of legal subdivisions. Forty acres is the smallest recognized unit, except where fractional. It is not necessary that losses and selections be exactly matched in quantity. They should correspond as nearly as legal subdivisions will permit and a reasonable approximation is sufficient.[131]

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[126] It was also decided that the company was not entitled to indemnity for two different overlapping grants to it, one being for a branch line. Had the overlap resulted from an earlier grant to another railroad, indemnity could have been claimed. Many minor issues were decided, the decision below partially reversed and the case remanded to the lower court for further proceedings as indicated in the opinion (376).

[127] Payne v. Central Pac. Ry. (1921) 255 U. S. 288; *affirming* with modification (1917) 46 App. D. C. 374.

[128] Northern Pac. Ry. v. McComas (1919) 250 U. S. 387, 392.

[129] Santa Fe Pac. R. R. v. Work (1925) 267 U. S. 511, 516; *affirming* (App. D. C. 1924) 295 Fed. 982. See also (1922) 49 Land Dec. 180, 184.

[130] Santa Fe Pac. R. R. v. Fall (1922) 259 U. S. 197, 200. But see (1923) 49 Land Dec. 522, 524 where these selections were cancelled.

The Supreme Court has said[132] regarding a forest lieu selection that:

> In principle it is plain that the validity of the selection should be determined as of the time when it was made, that is, according to the conditions then existing.

The only exception to the general rule before stated respecting the time as of which the character of the land—whether mineral or non-mineral—is to be determined is one which in principle and practice is confined to railroad land grants.

Mineral Lands Are Excepted From Railroad Grants[133]

The grants to railroads which crossed the mining states invariably specifically excepted "all mineral lands" from their operation.[134] This was but a reflection of the times. The miners, who had pioneered in the rugged wilderness of the West and who had endured heartbreaking hardships in their search for gold and other metals, considered themselves primarily responsible for the development and growth of this new land. They were jealous of any interference with their mining activities, so much so, that, through their influence, the extension of the public land surveys into the region of their operations was in many cases postponed for years. Mining claims under their own rules and customs could also be located on unsurveyed public domain, but filings under other public land laws had to await survey. Naturally, they viewed with apprehension the proposed enormous grants of odd-numbered sections on each side of the transcontinental lines, which necessarily would for great distances traverse the scenes of their activities. In order to protect the mining industry, the railroad grants were expressly confined to non-mineral lands.[135] Justice Field[136] reflected this feeling when he said in the case of *Barden v. Northern Pacific Railroad*[137] that if the railroad's contention in that case were to prevail and it was awarded the vast mineral wealth embraced in some 80,000 square miles of public domain to which it was entitled under its grant, "It would render the plaintiff corporation imperial in its resources—one that would far outshine 'the wealth of Ormus and Ind.' " In spite of the expressed will of Congress to except mineral lands from the railroad grants, the uncertainties which were bound to arise resulted in serious conflicts and claims of ownership which persist to this day. We have discussed the time when the title to lands acquired under these railroad grants would take effect and have seen that, like the grants of school and swamp lands, the railroad title would, when acquired, ordinarily relate back to the date of the granting act. This doctrine was urged by the railroads as applicable to their land grants. Some of the early trial court decisions[138] held that the railroad grant mineral exception only applied to lands known to be mineral at the date of the railroad granting act. Such a ruling, if sustained, would have worked incalculable hardship on countless miners who had taken up mining claims in the vast areas penetrated by the transcontinental lines. The *Barden* case raised the issue squarely. The place land there involved was claimed by the railroad under a grant of 1864. Its line had become definitely located in that vicinity in 1882. Quartz mining claims were located on the land in 1888. Two federal judges sat at the trial. Their views were in conflict on this question of relation of title back to the date of the grant.

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[131] Southern Pacific Co. v. Fall (1922) 257 U. S. 460, 462, 464; *affirming* (App. D. C. 1920) 263 Fed. 637. The rule of approximation is applicable to indemnity selections. (1918) 46 Land Dec. 279, 281.

[132] Wyoming v. United States (1921) 255 U. S. 489, 496.

[133] LINDLEY, MINES §§ 158-162.

[134] Lands valuable for coal and iron were expressly included in the railroad grants because those minerals were essential to railroad construction and operation. But chromite, though it contains iron, may not be acquired by a railroad under its grant. Only where the iron value predominates is it iron bearing land within the meaning of the act. (1918) 46 Land Dec. 476, 478. A deposit of shale valuable only for the manufacture of cement is not mineral land. (1914) 43 Land Dec. 325; but a bed of diatomaceous earth is, (1916) 45 Land Dec. 223. It is not necessary that mineral be actually discovered on the land to justify the determination that it is mineral if indications give it mineral character in a broad sense. (1916) 45 Land Dec. 25; also see (1916) 45 Land Dec. 327.

[135] So that there would be no misunderstanding on this score, Congress, January 30, 1865, adopted a joint resolution (13 Stat. 567) restating its policy of reserving mineral lands from railroad grants. See U. S. v. Sweet (1918) 245 U. S. 563, 568.

[136] Justice Stephen J. Field was eminently qualified to write the opinion in this case, for, prior to his elevation to the Supreme Court bench, he had for many years practiced law in the mining regions of the Sierra and later was on the Supreme Court in California. He brought to the Supreme Court of the United States a first hand knowledge of mining and land problems of the West.

[137] (1894) 154 U. S. 288, 331. While Judge Lindley has discussed this case at length (§ 154), its importance merits a brief restatement here to serve as a background to what follows.

Justice Field in the Supreme Court's opinion stated that Congress made it "as plain as language can make it" that its intention "was to exclude from the grant actual mineral lands, whether known or unknown, and not merely such as were at the time known to be mineral." The belt of territory included in the grant was known to embrace great quantities of minerals. The policy of Congress to exclude mineral lands and reserve them for special disposition was reflected in all its grants of public lands in aid of railroads (317-318). This rugged region was largely unexplored. It was inconceivable that the United States would "give away to a corporation of their own creation not only an imperial domain in land but the boundless wealth that might lie buried in the mineral regions covered by 80,000 square miles." (318-319.) It was recognized, however, that it would not be wise to leave the question of mineral or non-mineral character of the land open indefinitely. It was for the best interests of the country that titles to lands and minerals should eventually be settled. Accordingly, since provision was made for patenting these railroad lands and for determining their character at that time, the court concluded that this question was to be decided and foreclosed as of the date of the patent. Prior to that date the question of mineral character remained open for determination (326-332).[139]

When Judge Lindley published his third edition the critical case of *Burke v. Southern Pacific Railroad Company* was pending before the

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[138] LINDLEY, MINES § 154.

[139] Justice Brewer wrote a vigorous and satiric dissenting opinion, concurred in by two other justices, contending that the mineral or non-mineral character of the land granted should be determined as of the date of the definite location of the road when the odd-numbered sections were first identifiable. The later case of Northern Pacific R. R. v. Sanders (1897) 166 U. S. 620, decided similar issues and the court adhered to its ruling in the Barden case without any dissent. Justice Brewer was still on the bench, but evidently recognized that the ruling in that case had become "the law of the land." The Sanders case is also of interest because it reiterated the ruling, already well established, that the miners' rules and customs were recognized as a part of the public land law long before Congress saw fit to legislate on the subject (634-635). In a still later case, Shaw v. Kellogg (1898) 170 U. S. 312, 339, the court comments on the division of opinion in the Barden case, but says that the only difference was as to the exact time when the legal title would pass free from the contingency of future discovery of minerals. The dissenters claimed that this occurred at the time of the filing of the map of definite location of the road and the prevailing opinion that it was the date of patent.

Supreme Court of the United States, having been certified there by the Circuit Court of Appeals (Ninth) for instruction upon designated questions of law.[140] He called attention to the fact that the discovery of oil in the San Joaquin Valley through which railroad lines extended, where the odd-numbered sections claimed as railroad lands checkerboarded a considerable portion of the valley floor, gave rise to acute controversies as to ownership of what proved to be immensely valuable oil lands.[141] In the *Burke* case, suit was brought against the railroad company to establish title to five sections of land which had been located in 1909 under the placer mining laws.[142] Fourteen years earlier, on July 10, 1894, patent had been issued to the railroad company for this same land. The Supreme Court[143] first decided that oil is a mineral within the meaning of the mining laws.[144] The court then followed the reasoning of the *Barden* case that, though mineral lands were excepted from the railroad grants, it became practically imperative "that an authoritative identification of the lands passing under the grant and of those excluded" be made, otherwise there would follow uncertainty of title, conflicting claims and inevitable litigation. The Land Department was the branch of the government to which was confided the identification of these lands and the issuance of patents. The purpose of the patents was to identify the lands granted. Their issuance was a confirmation of the company's right and title (683-687). The court noted the *Barden* case as holding that the question of mineral or non-mineral character of the land "remained an open one until the issue of a patent," and that this same rule prevailed in the homestead, desert land, timber and stone and other public land laws. The settled rule in all of them has been that the mineral or non-mineral character of the land is a question for determination by the Land Department. Once patent issues, it is to be taken, on collateral attack, as conclusive evidence of the non-mineral character of the land (687-691). The court noted that in 1892, or two years prior to issuance of patent, the same lands had been located by others, but there was no privity between them and complainants for these earlier claims had been abandoned (693). The fact that the patent itself, with the express consent of the patentee, recited that the mineral lands were excepted from its operation was held to be an invalid insertion by the Land Department, which had no power to extend the exception of the statute (693-705). The fact that the patent might have been issued by the Land Department without any investigation as to the character of the land did not, in the opinion of the court, alter the situation. A patent under such circumstances is irregularly issued, but "it is not void and therefore passes title." The government might attack such a patent in a direct suit for its annulment if the land was known to be mineral when the patent issued (710).[145]

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[140] Because of the importance of the case, Judge Lindley devoted several pages to its consideration. LINDLEY, MINES § 161.

[141] The writer has already briefly discussed this situation. Colby, *The Law of Oil and Gas* (1942) 30 CALIF. L. REV. 245, 258.

[142] At that time public lands valuable for oil and gas could be located under the placer mining laws. Subsequently, Congress, by the Leasing Act of 1920, made such lands subject only to lease from the government. Colby, *op. cit. supra* note 141 at 262.

[143] Burke v. Southern Pacific R. R. (1914) 234 U. S. 669.

[144] *Id.* at 676. Colby, *op. cit. supra* note 141 at 247.

[145] The Burke case was followed in People's Development Co. v. Southern Pac. Co. (C. C. A. 9th 1922) 277 Fed. 794.

Acting on this last suggestion, the United States, itself, brought suit to set aside some of these railroad patents.[146] Patents had been issued in 1904, at which time it was claimed by the government that the lands were known to be mineral and that this fact had been concealed from the Land Department. The Supreme Court reviewed the conflicting testimony and concluded that at and prior to the date of the patent the known conditions were such as reasonably to engender the belief that the lands contained oil of such quality and in such quantity as would render its extraction profitable and justify expenditures to that end (13-14) and ordered cancellation of the patents.[147]

Work done and discoveries of mineral subsequent to the date of the railroad patent are incompetent and immaterial, for the condition as of that date cannot be proven by the most fallible of criteria, subsequent events. However, the subsequent discoveries are of account in their influence upon witnesses and in weighing their testimony.[148]

Another government suit to set aside a railroad patent, issued in 1905 and which contained a deposit of limestone, was successful in part only, because all of the odd-numbered section was not proved valuable for mineral and known to be at the date of the patent.[149]

A railroad patent was ordered issued for one-half of a 40 acre tract that was proven to be non-mineral, the other half being mineral. The court said that the Land Department regulations cannot destroy rights vested under a railroad grant even though tracts containing 40 acres are the minimum legal subdivisions recognized under the government surveys. The court said, if the non-mineral portion cannot be patented to the railroad, how can it be patented to any one else?[150]

The United States has a right to maintain a suit to vacate a railroad patent issued through error or mistake where at the time of issuance the question of mineral character was still pending before the Land Department.[151]

Railroad Lands and the Extralateral Right

With all the countless thousands of railroad patents issued in the mining regions of the West, it is remarkable that only comparatively recently has a reported case[152] arisen definitely deciding the right of the owner of a mining claim to exercise an extralateral right by following the vein apexing in his mining claim down on its dip as it penetrates beneath railroad patented land.[153] The paucity of cases involving the right of vein apex owners to penetrate extralaterally beneath agricultural lands generally, is also noteworthy.[154] In the *Ames v. Empire* case, the evidence established the fact that the Pennsylvania and Jefferson lode mining claims were located and worked in accordance with the miners' rules and customs of the Browns Valley mining district in Yuba County as early as 1863.[155] The railroad land underneath the surface of which the Pennsylvania-Jefferson vein apexing in those claims extended on its dip or descent into the earth, was patented June 14, 1880, pursuant to the Railroad Grant Act of July 25, 1866.[156] The owners of the railroad title contended that since the first mining act of Congress expressly recognizing the rights of the miners (who previously had gone on the public domain without specific statutory authority) was enacted July 26, 1866,[157] the day following the enactment of the Railroad Act, the railroad title by the doctrine of relation took precedence over the mining title. The court held[158] that since the Mining Act of 1866 was a confirmation and recognition of previously existing mining claims initiated in 1863 under the miners' rules and customs (218) and since the Railroad Act of 1866 expressly excepted mineral lands (219), the mining title had priority in time over the railroad title. The court also held that the mineral exception in the railroad patent must be determined as of the date of issuance of that patent and could not by the doctrine of relation be referred back to the date of the Railroad Act (221). The court concluded that the extralateral rights of the mining claims took precedence over the railroad title and that the railroad patent conveyed only the surface of the railroad land and also the subsurface that was not already subject to existing extralateral rights.[159] The Pennsylvania claim had been patented August 18, 1880, but this fact was immaterial, because it is elementary mining law that a mining location held under a possessory right, "for all practical purposes of ownership, is as good as though secured by patent."[160]

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[146] United States v. Southern Pac. Co. (1919) 251 U. S. 1, *reversing* (C. C. A. 9th 1918) 249 Fed. 785. See also (S. D. Cal. 1915) 225 Fed. 197; (N. D. Cal. 1919) 260 Fed. 511, where cancellation of railroad patents issued in 1894 to oil property worth a quarter of a billion dollars was refused on the ground that it was not then known to be mineral land.

[147] The federal statute of limitations barring suits to set aside patents would have barred this action, were it not for the fraud charged and proved. (1891) 26 Stats. 1093; 16 U. S. C. 607 (1946).

[148] United States v. Northern Pac. Ry. (D. Mont. 1924) 1 F. (2d) 53, 57.

[149] U. S. v. Southern Pac. Co. (S. D. Cal. 1926) 11 F. (2d) 546, 550.

[150] Work v. Central Pac. Ry. (App. D. C. 1926) 12 F. (2d) 834.

[151] U. S. v. Southern Pac. Co. (S. D. Cal. 1930) 43 F. (2d) 591, 592.

[152] Ames v. Empire Star Mines Co. (1941) 17 Cal. (2d) 213, 110 P. (2d) 13, *cert. denied,* (1941) 314 U. S. 651; the decision of the District Court of Appeals, 93 P. (2d) 635, was affirmed but on different grounds. This case will receive more detailed consideration in a subsequent article, dealing with the subject of Extralateral Rights.

[153] Judge Lindley in § 597, 1426, comments on a case, Wedekind v. Bell (1902) 26 Nev. 395, tried in Nevada, where the trial court upheld the right of the apex proprietor to follow the vein extralaterally beneath railroad patented land, but the Nevada Supreme Court dismissed the appeal on technical grounds without deciding the case on its merits.

The Jefferson claim was never patented but was abandoned and subsequently relocated in 1891. The California Supreme Court stated, with reference to the railroad land, that both "the Pennsylvania and Jefferson mines received full extralateral rights "and could mine thereunder by virtue of the Mining Act of July 26, 1866." (219). The decision also pointed out that the owners of the railroad land were estopped from contesting the extralateral right of the Jefferson claim by virtue of a reservation to that effect in a deed made by one of their predecessors

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[154] We have two outstanding cases. East Cent. E. M. Co. v. Central Eureka Co. (1907) 204 U. S. 266, 272, *affirming* (1905) 146 Cal. 147, where the right of the mining claimant to follow the vein extralaterally beneath a later agricultural patent was upheld. The same ruling was made in Penn. Consol. Min. Co. v. Grass Valley Expl. Co. (N. D. Cal. 1902) 117 Fed. 509, 516. The principle of these cases is indistinguishable from the similar situation involving railroad land patents. The reason that there are so few such cases is probably due to the fact that fewer agricultural patents were obtained in the mining regions.

[155] It is of historical interest to note that cases involving these claims are reported in Kent v. Snyder (1866) 30 Cal. 666; Pralus v. Jefferson M. Co. (1868) 34 Cal. 558; and Pralus v. Pac. G. & S. M. Co. (1868) 35 Cal. 30.

[156] (1866) 14 Stat. 239.

[157] (1866) 14 Stat. 251. Congress had previously many times recognized that the miners were working on the public domain. Colby, *Mining Law in Recent Years,* Part I (1945) 33 CALIF. L. REV. 368, 371, note 13.

[158] This opinion was written by Judge Traynor, a former member of the faculty at Boalt Hall of Law.

[159] LINDLEY, MINES § 613 was cited on this point.

[160] Wilbur v. Krushnic (1930) 280 U. S. 306, 317; Ickes v. Development Corp. (1935) 295 U. S. 639, 644.

(223), so that two grounds are given for sustaining the extralateral right of the Jefferson claim.[161]

A case decided more recently (1946) in El Dorado County[162] involved a situation similar to that presented by the Jefferson lode mining claim in the preceding case. There was evidence to show that the ground included in the patented Penobscot lode mining claims was located as early as 1864 and that it had been claimed as a mining claim continuously since then. Adjoining ground, beneath which the vein apexing in the claim extended extralaterally on its dip, had been patented in 1905 as railroad land. At the date of the railroad patent there was a valid mining location in existence embracing the area, later patented as the ''Penobscot,'' which included this apex. Subsequent to 1905, this mining claim was ''jumped'' and located adversely as the ''Penobscot.'' The trial court held that the right to the vein extralaterally beneath the surface of the railroad patented land had automatically been carved out of and reserved from that land by reason of the existence at the date of the railroad patent of the mining location including the apex of the vein. The subsequent relocation of the mining claim carried with it the extralateral right to the vein which had already been permanently carved out of and reserved by operation of law from the overlying railroad patented surface. This holding is in consonance with Judge Lindley's expressed views and also those of the other textwriters on the subject.[163]

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[161] Judge Carter dissented from the prevailing opinion which was concurred in by five other judges, (1941) 17 Cal. (2d) 213, 226, 110 P. (2d) 13.

[162] Middle Fork Gold Min. Co. v. Green. An appeal was dismissed on technical grounds (1947) 79 Cal. App. (2d) 350, 197 P. (2d) 363, so there is no reported opinion on the merits.

[163] LINDLEY, MINES § 612; COSTIGAN, MINING LAW § 118m (1908); MORRISON, MINING RIGHTS, 210 (16th ed. 1936); RICKETTS, AMERICAN MINING LAW §§ 172, 945; (1931); SNYDER ON MINES §§ 760, 865 (1902); MARTIN, MINING LAW § 323 (1908); KENNY, THE LAW OF THE APEX, 210 (1914). The vein on its dip "constitutes no part" of the adjoining land beneath the surface of which the vein extends. Tyler M. Co. v. Last Chance M. Co. (1898) 90 Fed. 15, 21. It cannot be recaptured by adverse possession of the surface. LINDLEY, MINES § 812.

QUICKSILVER DEPOSITS OF THE CACHUMA DISTRICT, SANTA BARBARA COUNTY, CALIFORNIA*

By Donald L. Everhart**

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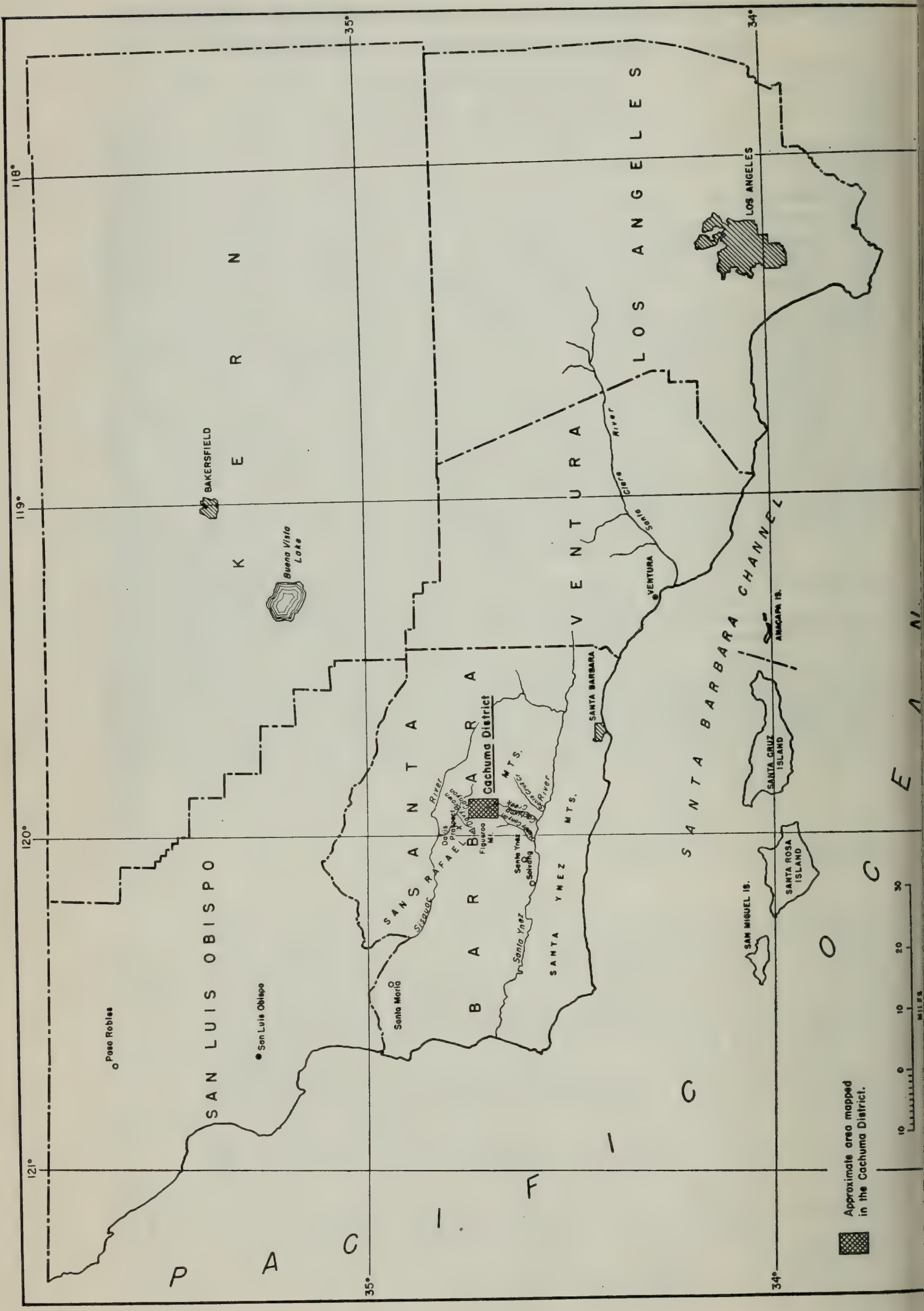
** Geologist, U. S. Geological Survey.


35°
34°
118°
119°
120°
121°
K E R N
BAKERSFIELD
Buena Vista Lake
L O S A N G E L E S
LOS ANGELES
V E N T U R A
VENTURA
Santa Clara River
S A N T A B A R B A R A
SANTA BARBARA
Cachuma District
S A N R A F A E L MTS.
SANTA YNEZ MTS.
Figueroa Mt.
Davis
Prospect
Sisquoc River
Santa Ynez River
Santa Ynez
Solvang
Cachuma Creek
Santa Maria
S A N L U I S O B I S P O
San Luis Obispo
Paso Robles
S A N T A B A R B A R A C H A N N E L
ANACAPA IS.
SANTA CRUZ ISLAND
SANTA ROSA ISLAND
SAN MIGUEL IS.
P A C I F I C O C E A N
Approximate area mapped in the Cachuma District.
10 0 10 20 30
MILES

ABSTRACT

The Cachuma district is 23 miles by road northeast of Solvang in the central part of Santa Barbara County, in the southern part of the Coast Ranges of California. To the end of 1945 the district had yielded 3,340 flasks of quicksilver with virtually all the production coming from the Red Rock and Lion Den mines. The Red Rock mine, in the central part of the district, was first developed in 1867 and was worked intermittently until 1921 when it was abandoned. Another period of production began in 1932 and ended in 1945. The adjacent Lion Den mine first produced in 1935 and became inactive early in 1944.

The rocks of the Cachuma district may be divided into three lithologic units. The Franciscan formations of Jurassic (?) age consists of arkosic sandstone, shale, chert, and greenstone which crop out in the southwest corner of the area. These rocks are intruded by large amounts of bastitic serpentine. A wedge-shaped block of sediments of the Monterey formation of middle and upper Miocene age underlies the central part of the district and consists of limy shales and shaly limestones. The northeastern half of the district is underlain by well-bedded sandstones, siltstones, and shales of the Knoxville formation of Upper Jurassic age. These sediments are intruded by several small sill-like bodies of dunitic serpentine.

The three lithologic units are separated by two steeply dipping, northwest-trending faults. Within the area underlain by rocks of the Knoxville formation three other distinct sets of faults have been mapped. One set strikes north and dips steeply east; a second set strikes east and dips moderately south; and a third single fault zone trends N. 30° E. and dips moderately to steeply southeast. The third zone cuts the other two sets and may be contemporaneous with the northwest-trending regional faults. Movement on all these faults has been recurrent.

All the quicksilver deposits occur along the northeast-trending fault zone at intersections with other structural features, such as sill contacts and other fault zones. A prominent north-trending fault zone is the principal structural feature intersected in the Red Rock mine and the east-trending fault zone shares the structural control in the Lion Den mine.

Cinnabar is the only quicksilver mineral recognized in the district and it is directly associated with earlier hydrothermal clay and carbonate. The cinnabar and clay and most of the carbonate fill open spaces, fractures, and shears in the rock, and some replacement of the rock by carbonate has occurred. No other sulfide except pyrite was identified.

Chances for discovering new ore in the district appear to be confined to possible extensions of a few of the known ore bodies in the two mines. The geologic mapping of the district, as limited in this report, has revealed no areas structurally favorable for large new ore bodies.

INTRODUCTION

Location

The Cachuma quicksilver district, near the center of Santa Barbara County, California, is principally in the headwater region of Cachuma Creek in the San Rafael Mountains of the California Coast Ranges (fig. 1). The heart of the district is on the western flank of Cachuma Mountain, but the area studied extends southward into the drainage area of Cachuma Creek and northward into the upper part of Davy Brown Canyon (pl. 74). The district is accessible from the villages of Santa Ynez and Solvang in the Santa Ynez Valley to the southwest. The two principal mines are 19 miles by road from Santa Ynez and 23 miles from Solvang. Eight miles of that distance are over a graveled road, which climbs nearly 2,000 feet from the floor of Happy Canyon to the mines, and certain sections of it are subject to damaging landslides during the winter months. The excellent roads in the Santa Ynez Valley and Happy Canyon are hard-surfaced and are usuable throughout the year.

Topography, Vegetation, and Climate

The area mapped in this study covers some 12 square miles of rugged, brush-covered mountain slopes and steep-sided canyons in the Los Padres National Forest. The heavy brush of the area, which is nearly impenetrable in places, consists largely of waist- to head-high manzanita, chaparral, and scrub pine and the few clearings are generally carpeted with yucca. The rainfall, which averages about 25 inches per year, occurs altogether in heavy and long-continued down-pours in the winter months and greatly increases the difficulties of mining during that period of the year.

History,[1] Production, and Ownership

The earliest recorded quicksilver mining in the Cachuma district was in 1867, when the original claim, probably known then as the Eagle, was located on the present Red Rock property (table 1). Early work in the district was highly sporadic and only moderate amounts of quicksilver were produced at irregular intervals until the 1930's. A small amount of development work was done on the old Santa Rosa mine (now Lion Den mine) at the time of World War I, but the claim was later abandoned.

J. G. Moore of Los Olivos, California, prospected the district extensively in the late 1920's and early 1930's, finally locating, in 1933, a claim on the Lion Den property, which he owned continuously to the time of this investigation. In 1936 the California Mercury Co. (Cal-Mer) took an option on the property and produced mercury until the end of June 1937, having installed a 30-ton plant in March 1937. The owners operated the mine once more until the spring of 1943 when the Wesco Mercury Reduction Co. of Los Angeles, with George L. Machris as president, took over the operation. The mine was closed in 1945.

On the adjacent Red Rock property, O. E. Hanno and Dr. Henry Hanze of Solvang produced a small amount of mercury, by retorting, in 1932. From early in 1935 to the end of 1938 the Santa Ynez Mercury Co. of Solvang, with Hans Peters as president, made a fair production of quicksilver using a 20-ton Herreschoff furnace. The most successful mining operation in the history of the Cachuma district was begun in October 1941 and concluded in September 1943 by the Cachuma Mining Co. of Los Angeles, a subsidiary of the Seeley-Mudd Corp. This company sold out in 1944 to George L. Machris, who operated the two mines in the district under the name of the National Mining and Milling Co., developing the Red Rock mine and producing quicksilver from it until late in 1945.

Previous Work, Field Work, and Acknowledgments

No geologic report on the Cachuma district and its mines, or on the immediately surrounding area has been published. However, a private report on the Lion Den property was written by Herman Fleck (date unknown), and a private geologic report and detailed geologic maps of the Red Rock mine were prepared for the Cachuma Mining Co. by E. H. Wisser, consulting geologist, in 1942. The second report, considerably augmented and revised by Conrad Martin, mining engineer for the company, was made available to the writer. R. N. Nelson has published a comprehensive report on the geology of a large area south and southeast of the Cachuma district.[2] His map ends about 2 miles south of the mines and continuations of several of the structural features shown on his map have been mapped in the Cachuma district.

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[1] Much of the historical data in this report is taken from: Ransome, A. L., and Kellogg, J. L., Quicksilver resources of California: California Jour. of Mines and Geology, vol. 35, no. 4, pp. 448-450, October 1939.

Field work done by the writer in the Cachuma district from January until May 1944 consisted of: (1) the geologic mapping of about 12 square miles in the vicinity of the mines, on a scale of 1 inch to 1,000 feet; (2) investigation of the Davis prospect, 5 miles northwest of the mines; and (3) detailed geologic mapping of the Red Rock and Lion Den mines on a scale of 1 inch to 30 feet. The various levels of both mines, and the two mines as units, were tied together by a surface plane-table triangulation net, and control for mapping each level was made by Gurley compass, plane-table, and tape traverses. John M. Nelson, of the U. S. Geological Survey, aided the writer in the surveying.

For friendly cooperation and hospitality during the course of the field work, the writer expresses thanks to all of the officials and employees of the operating mining companies and to the staff of the Los Padres National Forest. During the preparation of this report, the laboratory facilities of the Ohio State University were available for the thin-section study and Dr. Carl Lamey of the University was most helpful in this work. Thanks also are due to Dr. Frank J. Wright, Department of Geology, Denison University, for making available the facilities of that University during the compilation of final maps and writing of the report. Valuable criticism of the text and maps has been contributed by R. E. Brown, A. H. Koschmann, and W. B. Myers of the U. S. Geological Survey.

GEOLOGY OF THE CACHUMA DISTRICT

Three main lithologic units have been distinguished in the Cachuma district (pl. 74). In the southwestern corner the area is underlain by the complex Franciscan formation of Jurassic (?) age. Mildly metamorphosed arkosic sandstone, contorted shale, chert, and altered volcanic rocks generally termed ''greenstone'' by California geologists occur in discontinuous and irregular masses. The area is also characterized by an unusually high proportion of serpentine intrusives which occupy nearly 65 percent of the area underlain by rocks of the Franciscan formation. A wedge-shaped block of sedimentary rocks of the Monterey formation of middle and upper Miocene age is northeast of the area of rocks of the Franciscan formation, separated by a steeply dipping, northwest-trending straight fault. Northeast of the block of sedimentary rocks of the Monterey formation, and separated by a more irregular northwest-trending fault, lies the third lithologic unit—an area of well-bedded sandstone, siltstone, and shale. These rocks, which underlie half of the district, are assigned by the writer to the Knoxville formation of Upper Jurassic age.[3] Near the center of the district they are intruded by several relativley small, sill-like bodies of serpentine, the edges of

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[2] Nelson, R. N., Geology of the hydrographic basin of the upper Santa Ynez River, California: California Univ., Dept. Geol. Sci., Bull. 15, pp. 327-396, 1925.

[3] The writer follows the concept of the age relations between the Franciscan group and Knoxville formation as expressed by Taliaferro in: Taliaferro, N. L., Franciscan-Knoxville problem: Am. Assoc. Petroleum Geologists Bull., vol. 27, no. 2, pp. 109-219, Feb. 1943.

Table 1. Ownership, operation, and production of mines in the Cachuma district, Santa Barbara County, California.

YEAR	RED ROCK MINE			LION DEN MINE			DAVIS PROSPECT		
	Owner	Operator	Production in flasks	Owner	Operator	Production in flasks	Owner	Operator	Production in flasks
1967	Red Rock Quicksilver Co.		"Small"						
188-							D. D. Davis		¼
1905	Sam Whitsett & Co.		57						
1907	Sam Whitsett & Co. J. P. Backstead		60						
1910	J. P. Backstead		75						
1912			85						
1913			97						
1914			"Small"						
1916	Not recorded		20	D. D. Davis		----			
1917			30						
1918			"Small"	Charles Clark					
1919			27						
1920			13						
1921			9						

1932	O. E. Hanno and Henry Hanze	64	J. G. Moore		5			
1933		125						
1934		90		Moore	40			
1935	Santa Ynez Mercury Co.	196						
1936		200		Cal-Mer Co.	29			
1937		395			205			
1938		61		Moore	3			
1939	Cachuma Mining Co.	?			21			
1940		119			20			
1941		262			5			
1942		613			1			
1943		241						
1944	National Mining and Milling Co.	8	Wesco Mercury Reduction		2	Atlas Mining Co.	W. O. Van Dyke	
1945		160			----			
	Total	3,007	Total		331	Total		¼

APPROXIMATE GRAND TOTAL—3,340 flasks.

which, in three places, have been hydrothermally altered to silica-carbonate rock.

The three structural units cited above are distinguishable in the field by the contrasts in topography and vegetation. The remarkable difference in topography on the two sides of the northwest-trending fault which separates the Franciscan formation from the Monterey formation is well-illustrated on the topographic map of the district. The area underlain by the Franciscan formation is open rolling country with comparatively gentle slopes and large topographic features. It is characterized by landslides, being irregular and hummocky in detail with small intermittent lakes and swamps on the long slopes. The area to the northeast, underlain by rocks of the Monterey formation, is much more rugged and is characterized by steeper slopes, with tall conifers sparsely scattered over a grass-covered terrain. The area underlain by the Knoxville formation exhibits extremely steep slopes, sharp canyons, and discontinuous, highly dissected mountain ridges. The ridges and sides of the canyons are covered with a thick carpet of manzanita, chaparral, scrub pine, and other brush.

The Knoxville formation and the serpentine intruded into it are the only rocks in the Cachuma district that contain quicksilver minerals. The rocks of the Franciscan formation in the southwest corner, which are typical of much of the ''quicksilver country'' in other parts of the California Coast Ranges, seem to be completely devoid of quicksilver minerals, and even silica-carbonate rock, the common host of quicksilver, is absent. Likewise, no quicksilver minerals are apparent in the sedimentary rocks of the Monterey formation, nor has there been extensive hydrothermal alteration of these rocks in the Cachuma district.

Franciscan Formation

Because the rocks of the Franciscan formation in the Cachuma district, unlike those in many other California quicksilver districts, have little apparent importance in regard to the quicksilver deposits they are treated only briefly in this report. The sedimentary rocks of the Franciscan formation in the district are typical of those throughout the California Coast Ranges. The sandstones are arkosic and have been metamorphosed or altered to the mild degree reflected by their widespread content of chlorite. The gray to black shales of the group are generally deformed and in places are carbonatized. Considerable quantities of dark-red or green chert occur in small irregular bodies. Likewise the scattered outcrops of greenstone are typical of those in other areas of the Franciscan group throughout the state. Most of the greenstone in the district occurs as fine-grained vesicular mafic flows, classed petrographically as basalt, which in their altered state are grayish green. The vesicles are relatively large and commonly are filled with finely crystalline calcite.

Knoxville Formation

The Knoxville formation in the Cachuma district consists of interbedded sandstone, siltstone, and shale. These sediments are well-bedded and their attitudes are constant over much of the district. The beds average about 6 inches in thickness, and in places are as much as 1 foot thick. The shales, siltstones, and sandstones are commonly well-defined and a minimum of gradation is observed between types.

The sandstone varies in character throughout the district. It ranges from fine- to medium-grained in texture, from greenish gray to olive drab, and from quartzitic to limy. It is uniformly high in ferromagnesian-mineral content, grading locally to graywacke, but is not as arkosic as the sandstone of the Franciscan formation. Weathering of the rock causes extensive limonitization of the dark minerals so the weathered outcrops are buff to brown. The rock is commonly carbonatized and almost all the sandstone observed in the district is cut by coarsely crystalline carbonate veins. Small unidentifiable wood fragments are included in much of the sandstone exposed on the western flank of Cachuma Mountain. In thin section the typical sandstone of the Knoxville formation is an equigranular mass of subangular to subrounded grains of quartz and minor feldspar with chlorite filling between the grains; late epidote is common. The grains are predominantly quartz, but there are a few grains of orthoclase, commonly sericitized, and sodic plagioclase. Euhedral magnetite, with limonite halos, is a minor constituent.

The siltstone of the area is generally of greener color than the sandstone. It is homogeneous and rather massive and breaks with a characteristic conchoidal fracture. Alteration is less marked in the siltstone than in sandstone, but limonite staining is characteristic. Some of the siltstone beds exposed near Cachuma Creek in the central part of the district carry well-developed sandy concretions which are as much as 2½ feet in diameter.

The shale of the Knoxville formation in the Cachuma district varies from grayish green through olive drab to dark brown. It is generally brittle and highly fissile in most places, and as it is the most incompetent rock of the formation it is contorted and fractured wherever sharp folding or faulting has occurred. Characteristically interbedded with the shale are widely distributed beds of shaley, fine-grained, dark-gray to black limestone. These beds, nowhere more than 6 inches thick, weather to a buff color.

The only identifiable fossils found in the Cachuma district are in the shale of the Knoxville formation near the intersection of coordinates 1109 E. and 1301 N. on the district map. This locality is in sec. 26, T. 8 N., R. 29 W., S.B. The fossils have been identified[4] as "*Aucellas,* resembling *Aucella piochii* (Gabb) . . . most probably of Jurassic age, although similar forms range into the basal beds of the Cretaceous." The fossil evidence, together with the lithologic and structural characteristics of the rocks, led the writer to correlate these sedimentary rocks with the Knoxville formation.

Serpentine Bodies

Serpentine bodies intrude the rocks of both the Franciscan formation and the Knoxville formation in the Cachuma district, but do not intrude any post-Knoxville rocks. The character of the serpentine emplaced in the two structural units differs, however, and descriptions of the two types may best be considered separately.

The serpentine bodies within the rocks of the Franciscan formation are generally long and narrow and may be either sill-like or dike-like in form depending upon their detailed (as yet unmapped) relationships to the structural features of the Franciscan formation. In outcrop, the serpentine weathers to a dark-brown to black color and tends to break into small angular blocks. It is characteristically pseudoporphyritic in texture with large bastite pseudomorphs, in a few places as much as an inch in length and a centimeter in width, set in a groundmass of fine-grained, dark-green serpentine minerals, presumably mostly antigorite. Apparently the ultramafic rock from which the serpentine was derived was coarse-grained and made up largely of pyroxene and olivine crystals. Upon serpentinization the pyroxene was converted to bastite and the olivine to the fine-grained antigorite ''groundmass.'' In many places, numerous chrysotile veins also cut the massive serpentine. The degree to which the serpentine has been sheared varies; in places the shearing is intense and the serpentine is light green in color and greasy in luster, with only small ''eyes'' of the darker massive rock remaining, but in other places the serpentine seems to be very little affected by any mechanical movement.

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[4] Imlay, R. W., U. S. Geological Survey, personal communication.

The serpentine masses which intrude the sediments of the Knoxville formation in the central part of the district are clearly sills and are much smaller than most of those within the rocks of the Franciscan formation. The serpentine of these sills varies somewhat mineralogically but most of it appears to be derived from dunite. Local bastite pseudomorphs indicate pyroxene in the dominantly olivine rocks of the original intrusive, but where this is so, there is a definite segregation of the bastite into certain portions of the sill. The typical dunitic serpentne of these sills, where it seems least serpentinized, is a medium-grained, equigranular, light-green rock which is altered to drab brown in places, or weathered white. It is massive and ''grainy'' in appearance and breaks into small rounded boulders. Examination of thin sections of these rocks shows that in spite of the dunitic appearance of many of them, the rock is wholly antigorite and chrysotile with minor amounts of magnetite and chromite. Not all the rocks of the sills are completely serpentinized, for prominent among them in places is a chlorite-rich rock so intimately associated with the serpentine that it is impossible to map the two rock types separately on a small scale. The chlorite-bearing rock is somewhat similar in appearance to the serpentinized dunite described above in that it is grayish-green in color and is equigranular and medium-grained, but it is notably different in texture, being intergranular or somewhat ophitic. A thin section of the rock shows a medium-grained interlocking mass of clinochlore crystals, presumably an alteration product pseudomorphous after pyroxene, and lesser amounts of lath-shaped carbonate masses pseudomorphous after plagioclase. A few sizable tablets of highly altered plagioclase appear to be near $Ab_{30}An_{70}$ in composition. Magnetite occurs along fractures in the chlorite. The rock thus appears to have been pyroxenite, containing minor amounts of feldspar, or it may have been a diabase locally associated with dunite.

The age of the intrusions in the Cachuma district may be placed as post-Knoxville and pre-Miocene, for serpentine intrudes rocks of Knoxville age and older; but does not intrude the rocks of the Monterey formation. Presumably, in view of the relationship of serpentine intrusives elsewhere in the Coast Range, the approximate age is earliest Cretaceous.

Monterey Formation

The Monterey formation is often termed Monterey shale by geologists in California because shale is by far the predominant rock in the formation. So it is in the Cachuma district, but there are also rare outcrops of other sedimentary rocks.

The typical shale of the Monterey formation in this area is fine-grained, gray to white, calcareous, and fissile. The peculiar characteristic which best distinguishes it is extensive replacement along bedding planes by dark-colored opal. No megascopic fossils were observed, but the formation presumably carries abundant siliceous microfossils, as it does in other parts of California. Extreme fracturing and shattering of the shale and subsequent limonite staining is common.

Thin beds of porous, shaly limestone are interbedded with the shale in some parts of the area. The limestone is fine-grained and is dark brown or dark gray to black, weathering white to buff.

Silica-Carbonate Rock

Some of the serpentine of the sills in the Cachuma district has been hydrothermally altered to silica-carbonate rock. All the outcrops of this rock are about a quarter of a mile southwest of the Red Rock mine camp along the borders of a sill that is cut by a prominent northeast-trending fault (pl. 74). Apparently the altering hydrothermal solutions were afforded upward passage along this fault. The age of the silica-carbonate alteration is presumably late Tertiary.

The main body of the sill is composed of granular dunitic serpentine, and a complete gradation is observed from the serpentine to the silica-carbonate rock, which to all appearances is identical to the host rock of many of the quicksilver deposits in the California Coast Ranges. The intermediate stage of this gradation is characterized by partial carbonatization of the serpentine, in which the original texture of the serpentine is well-preserved. Further alteration has caused complete carbonatization and extensive silicification in some places to form an extremely hard, massive, resistant rock, which is commonly veined with coarsely crystalline dolomite, ankerite, and white quartz. A bright-green platy mineral, probably a chlorite, is characteristic, and a mineral tentatively identified as allophane was noted. The largest and most prominent silica-carbonate rock body, near the fault at its north end, is leached and limonitized to such an extent that it is punky, and under a hammer blow it produces a hollow thudding sound.

Thin sections of the silica-carbonate rock from this district generally show fine-grained, rather equigranular masses of dolomite (and other carbonates in isomorphous series with it), and quartz. Interlocking granular quartz masses in ill-defined stringers and blobs apparently are later than most of the carbonate mass. A few late carbonate veins, however, cut all the other minerals of the rock. Black pitchy hydrocarbons occur in some of the silica-carbonate rock, closely associated with the carbonate veins. Some of the veins are stained, and the open spaces filled with considerable limonite, probably an alteration product from magnetite "clouds" that are common in the rock. Cinnabar in painty flecks is rare in the silica-carbonate rock of this district, and pyrite is only slightly more abundant. No other sulfides were seen and recognized by the writer.

Surficial Rocks

Alluvial fill constitutes mappable geologic units in two localities in the Cachuma district. An imperfectly developed and partially dissected alluvial fan has been formed below the Lion Den mine where the gradient of the western slope of Cachuma Mountain becomes markedly gentler. Although only 5 to 8 feet in maximum thickness, the detrital material covers an area of about 150 acres. Alluvial material also fills the valley of Cachuma Creek below Lion Canyon.

Structure

The three-way division of the Cachuma district by two major northwest-trending faults has been shown.

The southwesternmost of these two faults, which brings the rocks of the Franciscan formation into contact with those of the Monterey formation, extends about 10 miles to the northwest of the district and about 15 miles to the southeast, according to R. N. Nelson,[5] who named it the Cachuma fault. However, the contact between the rocks of the Franciscan formation and the Monterey formation is reported to be depositional about 6 miles northwest of the district [6] so the northwestern extension of the fault is uncertain. In many places it forms the northeastern contact of an elongate northwest-trending belt of rocks of the Franciscan formation, which are exposed in a long strip in central Santa Barbara County. In the 4½-mile segment over which this fault is mapped in the Cachuma district, it uniformly strikes N. 50° W., and because of its nearly straight trace appears to dip steeply to the northeast. Southeast of the district, the dip is reported to be about 60° NE.[7] The serpentine adjacent to the fault is everywhere sheared along planes, the horizontal traces of which are essentially parallel to the fault. The adjacent shale of the Monterey formation is so fractured and contorted that no reliable attitudes can be recorded near the fault, but in the small canyon below the Peacock chrome mine an excellent section of the Monterey formation is exposed, which shows the beds dragged to a vertical attitude from the regional near-horizontal attitude.

The other major northwest-trending fault in the district, separating the rocks of the Monterey formation from the Knoxville formation, is more irregular in its trend. In the southern part of the area it strikes N. 45° W., but turns to an average of N. 23° W. through the central part of the district, and then swings back to N. 40° W. In the central and southern sectors, the fault is apparently nearly vertical. The one large exposure of the contact on the Figueroa Mountain road shows that its dip is generally vertical, though somewhat variable. To the northwest, the dip is steeply to the southwest.

The structure of the three main blocks in the district has been studied in varying detail, with the greatest emphasis on those features that are related to the quicksilver deposits. For the purposes of this report, the highly complex and discontinuous structural features within the rocks of the Franciscan formation may be considered as unmapped and are not described.

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[5] Nelson, R. N., op. cit.

[6] Myers, W. B., personal communication concerning senior thesis for the University of California at Los Angeles.

[7] Nelson, R. N., op. cit., p. 379.

The structural features within the block of the Monterey formation are locally variable, the beds being deformed on a small scale. In general, however, the sedimentary rocks of the Monterey formation are nearly flat lying in the narrow southeast part of the wedge, are thrown into a series of folds with northwest-trending axes in the vicinity of Lion Canyon, and are thrown into folds with west-trending axes in the area north of Ranger Peak. In the central part of the wedge, steeply dipping joints parallel the axial planes of the folds.

The structural features within the strata of the Knoxville formation are pertinent to the control of the ore bodies and have received the greatest attention.

The bedding of the Knoxville sedimentary rocks is generally uniform in attitude over most of the area mapped. Throughout most of the district these beds strike N. 20°-50° W. and dip moderately to steeply northeast, although in the west-central part of the exposure of Knoxville formation, some of the beds dip steeply. The only area of intense and intricate deformation of these sediments was mapped within the square mile lying north of the Lion Den mine. Several areas of cross folding and general contortion are in this part of the district, the most prominent of which is near the northernmost switchback on the Cachuma Mountain road (pl. 74).

Three main sets of faults cut the sediments of the Knoxville formation in the Cachuma district. The first set strikes about due north and dips steeply east; the second strikes nearly due east and dips steeply south; and the third, which is actually a single fault zone, strikes N. 30° E. and dips steeply northwest to vertical where it is exposed southwest of the Red Rock mine, and steeply southeast from that point northeastward. All three fault systems afforded structural control for the ore deposition, but the first and third are more important than the second.

The principal fault of the north-trending set is exposed in all levels of the Red Rock mine and on the surface throughout the length of the property. It is expressed topographically by a straight-trending ledge which is resistant to erosion owing to the extensive mineralization of the fault. From the Red Rock mine the fault trends south into the drainage area of Deep Dry Canyon and averages 75° E. in dip. In its southern sector, as at the mine, the fault has been highly carbonatized, and carbonates that fill open spaces and replace the sandstone grade away from the fault along bedding planes in the thick sandstone members of the Knoxville formation. Drag folding in the beds adjacent to the fault indicate that the east side has moved south, at least along the southern part of the fault.

A second fault belonging to the same north-trending system is exposed 200 feet east of the first. It has been traced south from the Red Rock mine road through the Sulphur Dome claim prospect pits and into the small valley to the south. This fault dips steeply east, and striae on the exposed fault surface near the Red Rock mine pitch 15° S. Like the first, it has been highly carbonatized.

Another fault assigned to this set of faults, although it trends several degrees west of north, is exposed as an impressive fault scarp defining the eastern edge of the large body of silica-carbonate rock in the central part of the district. The scarp, ranging from 50 to 100 feet in height, strikes about N. 18° W. for 1,300 feet, and the fault can be traced several more hundreds of feet to the southeast. Northeast dips vary from 68° to 80° and striae on the fault surface uniformly pitch northwest from 20° to 30°. Fault gouge, which has been carbonatized, is exposed within a few feet of the fault along its entire length.

Faults of the east-trending set are relatively few in number and short in linear extent. Most of them are concentrated in a 300-foot zone a few hundred feet north and northwest of the Lion Den mine. Here most of the faults dip steeply south, although one or two have steep dips to the north. Like the faults of the first set, they have been carbonatized, but to a much lesser degree than the north-trending group farther south. A pair of faults belonging to this set are explored in the underground workings of the Lion Den mine, but have little or no surface expression. One strikes N. 60°-80° W. and dips moderately to steeply southwest. The other strikes east and dips moderately south. Minor faults of similar attitude are exposed on the surface and in the underground workings of the Red Rock mine.

The third fault system within the Knoxville formation is actually a single complex fault or fault zone. This fault, which is probably the most important geologic structure in the district relative to the quicksilver ore bodies, has a uniform trend through the district, and was mapped over a greater distance than any other fault within the Knoxville formation. It is traceable along a general N. 30° E. strike for at least 2 miles. The northeast-trending fault offsets the large serpentine sill southwest of the Red Rock mine; there it dips vertically or steeply northwest and displays horizontal striae on the latest fault surface. Offset of the sill indicates that the northwest side moved northeast. The fault is exposed throughout the surface of the Red Rock property and in the underground workings of that mine, where it dips steeply southeast. Striae on the fault surfaces of the outcrops at the Red Rock mine pitch about 30° SW. The fault is readily traced between the two mines and throughout the Lion Den property where it is the main southeast-dipping fault zone of the mine and was the primary control for the ore deposition. Numerous exposures to the northeast, including that at the Lost Chord claim near the top of Cachuma Mountain, mark its continuity as far as the headwaters of Fish Creek, where it apparently dies out. As in the case of the north-striking faults, the evidence suggests recurrent movement along the entire length of the northeast-trending fault zone, although the aggregate offset is not great. Wide zones of mineralized gouge are commonly cut and slickensided by late faults. As in the north-trending faults, the mineralization along this fault, particularly the carbonatization, was intense. The mineralization appears to have been weakest near the intersection of the northeast-trending fault and the northwest-trending fault that separates the Monterey and Knoxville formations. This seemingly anomalous condition may be explained by the possibility that the faults near the intersection were so tightened by the wedged blocks that most of the mineralizing solutions were guided to the northeast, where upward access was easier.

The age relationship of movements on the faults mapped in the Cachuma district is somewhat obscure. Recurrent movement has introduced complication, and offsets are rarely large enough to be traced with certainty. Broad relations indicate, however, that the northeast-trending fault zone in the Knoxville formation is later than the north-striking and east-striking sets, which are probably contemporaneous.

The two large northwest-trending faults that bound the block of the Monterey formation are in turn contemporary with or younger than the first movement on the northeast-trending fault zone.

The age of all the major faulting in the Cachuma district is thought by the writer to be post-Pliocene. R. N. Nelson has demonstrated that both the Cachuma fault and several faults within what he terms the San Marcos block to the south of the district are younger than the Paso Robles formation and are therefore younger than Pliocene.[8] The faults within the Cachuma district, other than the Cachuma fault and its split to the northwest, are similar in character and attitude to some of those in the San Marcos block and may be plausibly compared to them in age.

MINES AND PROSPECTS

Red Rock Mine

Description of Workings and Plant

The Red Rock mine explores a prominent, narrow, north-trending ridge in the center of the Cachuma district. Four main levels, named the 5, 6, 7, and 8 levels, total nearly 6,200 feet in length and are driven in the interval between 2,854 and 3,172 feet above sea level (pl. 75). All the levels are adits. Narrow stopes connect all the levels of the mine and raises connect with surface glory holes from all except the 8 level.

Broken rock from the mine is trammed directly to the surface. Waste dumps have been built up at each of the portals and each, with the exception of the 5 level, has its own grizzly and ore bin for sizing the broken ore. The ore is hauled from the bins in trucks to a large storage bin above a reduction plant, some 300 feet directly west of the 8 level portal. The rotary furnace in the plant measures 2 by 50 feet and its daily rated capacity is 50 tons, although the Cachuma Mining Company, in its 2 years of treating ore from the Red Rock mine, achieved only a 35-ton daily capacity.

Geology

The rocks exposed in the Red Rock mine are assigned to the Knoxville formation. Siltstone, ribboned and interbedded with shale, is by far the most common rock in the mine. In a few places, sandstone beds grading laterally into and interbedded with siltstones persist for as much as 200 feet along the strike and attain thicknesses of as much as 25 feet. Sandstone is particularly common in the southwestern parts of the 6 and 7 levels and in the northeastern parts of the 5 and 8 levels. Ore deposition was apparently little affected by the difference in sediments, and lithologic control along beds is almost entirely lacking. For this reason, no attempt was made to record on the mine maps the details of the lithology.

Bedding that has not been disturbed by faulting and shearing is rather uncommonly observed in the mine because all the workings are close to the fault zone that constitutes the control for the ore bodies. Adits, and exploratory and connecting crosscuts, however, explore enough unfaulted ground to indicate a constant bedding attitude. Unfaulted beds strike from north to N. 50° W., and dip from 60° NE. through vertical to 80° SW.

Faults. Three groups of faults, corresponding in general to the district groups, are recognized within the Red Rock mine.

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[8] Nelson, R. N., op. cit., pp. 389, 396.

The general north-south orientation of the mine workings is due to a thorough exploration of two parallel north-trending fault zones and a less complete exploration of a third zone; the three fault zones together comprise one group of faults. The most thoroughly explored of these fault zones has been designated as the Main vein [9] and has been followed on all levels of the mine and in the stopes connecting them over a total length of more than 1,200 feet. Segments have been explored through a vertical interval of 530 feet. The term ''fault zone'' is used because much of the Main vein is a series of anastomosing small faults with curving planes, which converge in places to form a single straight fault plane. This series of small related faults has produced a zone, ranging in thickness from a few inches to 8 feet, in which the sediments are sliced, shattered, and altered. The dip of the Main vein is east, varying from vertical to 60° (pl. 77). Recurrent movement along all parts of the explored fault zone is shown by slickensiding of the altered and mineralized fault gouge and breccia produced by former fault movements in the same zone. Drag in the bedding adjacent to the fault indicates that most of the movement shifted the west block north relative to the east block. Essentially all the striae on the slickensides pitch south at angles from 0°-40°, indicating that the fault is normal.

The second of the north-trending faults is the East vein which nearly parallels the Main vein and which is exposed on all but the 5 level. It dips 60° W. to vertical, and projections indicate that it merges with the Main vein about 60 feet below the 8 level in the southern part of the mine (pl. 77).

The third north-trending fault of the mine is much less explored than the other two, being followed for 130 feet only on the 7 level, near its southern end. There it is 40 feet west of the Main vein and parallels it, dipping steeply east. No reliable projection of this fault to other parts of the workings can be made, although it is possible that it is the same fault as that shown to be cut off on the 7 level by the later Southwest vein at a point 75 feet from the entrance to the Southwest vein drift (pl. 75). If so, the fault dips more gently east in its northern part than in its southern part. On the 6 level another possible projection of this fault is the fault cut off by the Southwest vein near the end of the Southwest vein drift (pl. 75).

The second group of faults in the Red Rock mine is thought to be made up of fractures on which there has been a little movement, formed in conjunction with the faults of the north-trending group, and related to the east-trending district faults. The faults of this group, called ''flats'' by the operators, vary from N. 65° E. to east in strike and dip 45°-60° south and southeast. Nearly all the fault planes are curved, and most of them are convex to the north. In general, these faults are confined to the wedge between the Main vein and the East vein. Several flats have been explored by drifts and slit stopes. The most prominent of these is the No. 3 flat which is stoped continuously, from the surface above the 5 level down to the 6 level. Another small segment of it is stoped directly above the 7 level (pl. 75). This flat is exceptional in that it cuts parts of the East vein and extends a short distance east of it between the 6 and

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[9] This and all other local fault names used in this report are those commonly used by the mine operators and by E. H. Wisser in his report and maps for the Cachuma Mining Co.

7 levels. At the 6 level, it cuts a western branch of the East vein but is terminated by an eastern branch of the same fault. Small stopes and drifts follow parts of flats in three other parts of the mine. No. 2 flat is exposed in the small south adit of the 5 level and is stoped for several feet below it. The ground adjacent to the intersection of the East vein and the southernmost flat of the central part of the 7 level is stoped for 20 to 25 feet above the level. The northernmost of the central 7 level flats is also stoped for a few feet above the level. Other smaller, less important faults of this group are shown on the mine maps.

A single narrow fault zone makes up the third major set of faults in the Red Rock mine. This zone, named the Southwest vein in the mine, is the major northeast-trending fault of the district; it strikes N. 30°-45° E. and dips 50°-70° SE. throughout the upper three levels of the mine. The major movements on this fault zone offset the other faults in the mine, moving the northwest side up and northeastward with respect to the southeast side. The offset of the north-trending faults is not great, probably not more than 30 feet, but considerable gouge and breccia, several feet thick in places, has been produced by the northeast faulting. This abundance of gouge constitutes an important difference between the Southwest vein and the faults of the north-trending groups.

The intersection of the Southwest vein with the Main vein is characterized by linking faults, complex fracturing and shattering of the rocks, and general distortion. Recurrent movement in both fault zones has caused anomalous relationships such as those observed in the northern part of the 5 level.

Mineralization. Faults of all three sets in the mine, as well as minor bedding-plane slips, are mineralized. Open-space filling has occurred in the faults and fractures, and there has been limited replacement of wall rock adjacent to the fault zones. This mineralization of the faults and induration of the adjacent rock has led the mine operators to regard nearly all the major faults in the mine as veins.

Three general types of mineralization may be observed. By far the most common type is carbonatization. Coarsely crystalline dolomite commonly fills open spaces throughout most of the mine and indurates favorable beds of siltstone and sandstone and pods of fault gouge and breccia without close relationship to any structural control. The carbonatization is much more pronounced in the rocks in and around the Red Rock mine than in any other sediments of the Knoxville formation in the district. Since the mine is the focal point of more faulting and fracturing than any other area, it is probable that the faults exposed in the mine have afforded easy access for carbonate-bearing solutions.

Open-space filling by a white, talc-like hydrothermal clay tentatively identified as dickite constitutes the second type of mineralization. This mineral occurs in great abundance in open spaces of the fault zones in the north-trending group and to a lesser degree of flats. Intensity of the clay mineralization is directly related to the intersection of the Southwest vein with the other structures, although the gouge along the northeast-trending fault zone itself is relatively poor in hydrothermal clay. Little or no dickite (?) is observed in the few workings which lie to the northwest of the Southwest vein, but to the southeast high concentrations of clay occur wherever the rocks are highly fractured, particularly adjacent to fault intersections. The dickite (?) occurs as far south in the mine as the southern part of the 7 level and the northern end of the 8 level and is thus more closely limited than the carbonate minerals. In the few places where age relations can be certainly determined, it is evident that the clay is later than the carbonate.

Metallic sulfide minerals, disseminated along faults and in small cracks and fractures, constitute the third type of minerals deposited in the mine area. The only certainly identified sulfides are cinnabar and pyrite. Metacinnabar is reported to have been found in a few places by former mine operators, but it may have been abnormally dark-colored cinnabar. Cinnabar is by far the more widespread of the sulfides, occurring in at least minute quantities in almost all parts of the mine. The center of quicksilver metallization is the intersection of the Main vein with the Southwest vein, particularly where that intersection lies adjacent to the No. 3 flat. In the rocks in this area are pockets of coarsely crystalline cinnabar which is later than the carbonate and hydrothermal clay. It, along with the other introduced minerals, fills open spaces in the fault zones, but is commonly slickensided by late recurrent movement. Cinnabar persists away from the main intersections, largely along the Main vein, both to the north and south, although metallization is much stronger to the south than to the north. The East vein likewise carries cinnabar throughout most of its exposed length. Away from the intersection, in the southern part of the mine, the cinnabar tends to be ''painty'' and is light-colored, although certain sections of the Main vein gouge carry enough fine-grained, disseminated crystalline cinnabar to constitute 5-pound ore. The Southwest vein, although not explored as thoroughly as the Main vein, carries comparable amounts of cinnabar in its well-developed gouge. As in the Main vein, the cinnabar tends to be ''painty'' away from the main intersections. Pyrite is much rarer than cinnabar and is observed largely as small late crystals in the Main vein.

Ore Bodies

At least six separate ore bodies have been recognized and mined in the Red Rock mine, although some were nearly continuous with others. Each are closely related to one of the structural features or a combination of structural features described in the foregoing paragraphs.

The richest ore shoot in the mine was irregularly pipelike in shape, and its position was controlled by the intersection of the Main vein and the Southwest vein. At the time of this field investigation, this steeply southward-plunging ore shoot had been continuously stoped from the surface to a point 10 feet below the 7 level, through a vertical interval of more than 140 feet. When the Cachuma Mining Co. stopped operations, a small winze from the 7 level is said to have bottomed in 10-pound ore, but the winze was subsequently flooded to the 7 level. The National Mining and Milling Co. drifted north on the 8 level during their 1944-45 development program to tap the downward extension of this same ore body. This was successfully accomplished, and by raising on it toward the winze from the 7 level, 30 flasks of quicksilver were produced from ore averaging 8 to 10 pounds per ton. The horizontal dimensions of this ore body varied throughout its plunge length, and in some places the shoot must be arbitrarily distinguished from adjoining ore bodies.

A second ore body, adjacent to the first throughout most of its length, was controlled by the No. 3 flat fault. The ore body had the form of a tabular wedge pointing and dipping southward, and was slightly convex downward. The upper part was over 150 feet wide near the surface above the 5 level and the mined width on the bottom end at the 7 level was less than 30 feet. The thickness of the ore body was nowhere more than 8 feet. Ore mined from this body, particularly that in the western part adjacent to the first ore body, is said to have been some of the richest taken from the mine. However, practically all of No. 3 flat has been explored, and the margins of the narrow bottom exposed on the 7 level show very low grade ore. Therefore it is assumed that this ore shoot has been worked out.

One of the largest stopes in the mine has completely explored a third ore body, controlled by the intersection of the East vein and No. 3 flat. This body has been worked largely between the 6 and 5 levels and for a short distance below the 6 level. The stope, although highly irregular in shape, is roughly cylindrical, with the maximum horizontal diameter, just above the 6 level, of about 80 feet. The intersection of the controlling faults of this body has been thoroughly exploited and as it pinches out downward, no further production from it can be foreseen.

A fourth small tabular ore body controlled by No. 2 flat fault was mined for a short distance below the 5 level where it adjoined the third ore shoot. It was never a major ore body in the mine, and appears to be thoroughly mined out. The controlling No. 2 flat fault appears to die out to the west of its present exposures.

The fifth and sixth ore bodies lie away from the central core of the mine, where the first four are clustered, and are somewhat less explored, thereby retaining more chance for undiscovered extensions. The larger of these bodies is thin and tabular and is controlled by the Main vein fault. It is explored for a total length of more than 500 feet, from the area just north of the north 6 level portal southward to the area around the main junction on the 8 level. It has been stoped continuously from the 6 level to the surface and from the 6 to the 7 levels. The body has also been mined between the 7 and 8 levels in the ground which lies directly above the mapped workings of the 8 level. The stopes exploiting this body are nowhere more than 10 feet wide, the ore being strictly confined to the gouge and breccia of the fault zone. Ore mined from this body was not high-grade but was evenly distributed, and constituted a relatively constant source of low-grade ore which did not yield more than about 4 pounds of quicksilver to the ton.

The sixth ore body in the Red Rock mine was also tabular and was controlled by the Southwest vein or northeast-trending district fault zone. It has been discontinuously mined in selected zones from the 5 level to the 6 level, and from the 6 to the 7 level. These zones, which are no more than 60 feet in maximum width, are all at their widest about 70-100 feet southeast of the intersection of the Southwest vein with the Main vein. The intensity of the shearing and the development of much gouge along the fault appear to have retarded the deposition of high-grade crystalline cinnabar within the fault zone itself, although considerable quantities of powdered, painty ore are present.

Suggestions for Prospecting

Two blocks of ground adjacent to the present workings appear to offer the best chances for extensions of known ore bodies. The most promising area is that near the intersection of the Main vein and the Southwest vein below the 8 level. Ore from this area at the 8 level contained as much as 10 pounds of quicksilver to the ton, and there is no indication that the ore body pinches out at a depth close beneath that level. The second most favorable block for development appears to be the downward extension of the fifth ore body, along the Main vein below the 7 and 8 levels. Although the grade may be assumed to be no more than 3 pounds to the ton, a considerable tonnage is indicated, affording a sizable reserve of low-grade ore.

Several other areas of the mine contain fair ground for exploration. None of these possibilities, however, is definite enough to give a clear idea of the size of possible ore bodies, or the grade of ore. The intersection of the Southwest vein with the north-trending vein west of the Main vein may have given rise to a possible ore body. Likewise, downward and lateral extension of the sixth ore body, along the Southwest vein, may yield moderate tonnages of low-grade ore. Exploration of ground adjacent to the northeast-trending fault zone, northeast of the intersection with the main vein, should be expanded. A little drifting in this area has been done on the 6 and 7 levels, but it should be carried farther to the east and northeast, where possible intersections of the Southwest vein with faults of the other groups suggest favorable spots for ore bodies. Drifting was started on the 7 level by the National Mining and Milling Co. in their 1944 development work, but for future exploration, diamond drilling might be more effective.

Lion Den Mine

Description of Workings and Plant

The Lion Den mine is about 620 feet to the northeast of the Red Rock mine, along the base of the west flank of Cachuma Mountain. Its 1,265 linear feet of underground workings, generally alined along a N. 30° E. direction and distributed through a vertical interval of 120 feet, consist of one inclined shaft, three main levels, one sublevel, and one major stoped area (pl. 76). The highest level, the Shop level, has a portal at 3,243 feet above sea level, the portal of the second, or Gulch level, is at 3,210 feet, and lowest or Bottom level, is at 3,183 feet. The mine in general lies at a higher elevation than most of the Red Rock mine, for the Bottom level is 10 feet above the northernmost part of the 5 level of the Red Rock mine. A shaft, inclined 70° in the central part of the Lion Den mine, connects the surface at 3,303 feet with the Bottom level and passes through the Shop level. A small sublevel, known as the Intermediate level, stems southward from the shaft at 3,223 feet. Stopes lie above all the levels, the largest extending upward from the northern part of the Gulch level to connect with a surface glory hole.

Ore from this mine is hoisted in a bucket through the inclined shaft to the surface, where it is trammed 50 feet to an ore bin, and fed through a grizzly to the crusher and the furnace at the Shop level. The furnace is a Gould-type rotary kiln having a 20-ton capacity. Its inside diameter is 20 inches; its length, 30 feet. The plant, except for the Diesel power unit, was in good order at the time of the investigation for this report, having been thoroughly reconditioned early in 1944.

Geology

The geology of the Lion Den mine is essentially the same as that of the Red Rock mine. The rocks are similar although the average grain size of the sedimentary rocks of the Knoxville formation in the Lion Den mine is coarser. Interbedded, medium-grained, gray sandstones and dark-gray to black siltstones are about equally abundant but shales are less common. The attitude of the bedding exposed in the Lion Den mine is comparable to that in the Red Rock mine. Away from the faults, the bedding strikes N. 25°-45° W. and dips 60° NE. to vertical. Many of the exposed beds, however, are near fault zones, where they are considerably affected by drag.

The Lion Den mine is located on the same northeast-trending district fault zone designated as the Southwest vein in the Red Rock mine. The main drifts of all three levels, the sublevel, and the stopes have been driven along this fault zone, which strikes N. 30° E. in the southern part of the mine and turns to N. 40° E. in the northern part. Dips vary from 65° to 80° SE. in the southern sector, and are somewhat gentler to the north. No offset or bending of the fault zone between the two mines is evident, for a line connecting the two nearest points of equal elevation on the fault strikes N. 30° E., a straight projection of the strike in both mines. As in the Red Rock mine, several feet of fine-grained gouge has been formed along the fault zone and recurrent movement is indicated. Drag in the bedding and striae on slickensided surfaces suggest that the northwestern block of the fault has moved northeastward and upward with respect to the southeast block.

Two faults comparable to the flats of the Red Rock mine are exposed by crosscuts in the Lion Den mine where they are cut by the northeast-trending fault. One fault, striking due east from the shaft on the Shop level and dipping about 60° S., is exposed over a distance of 50 feet. The other, explored by the 200-foot crosscut on the Gulch level, is highly undulatory but in general strikes N. 63° W. and dips 50°-65° SW. It is cut by a series of small vertical faults which strike about N. 25° W., and are concentrated near the west end of the crosscut, where both they and the flat are cut by the main northeast-trending fault (pls. 76 and 78). Nearly vertical north-trending faults, cut by the northeast-trending zone, are also represented in the Lion Den mine in the east drift of the Shop level and at the crosscut junction on the Gulch level.

The mineralized rock in this mine is identical with that described for the Red Rock mine. Carbonatization has been general, and the deposition of dickite (?) was closely controlled by fault zones and especially fault intersections, as was the deposition of the sulfides of mercury and iron. Some barite is associated with the coarsely crystalline carbonate veins in the Gulch level crosscut.

Ore Bodies

As in the Red Rock mine, the location of ore bodies in the Lion Den mine has been determined by the fault zones and their intersections. All the explored parts of the northeast-trending zone contain some cinnabar except in the northeast end of the Gulch level. Tabular ore deposits extend 20 to 30 feet above all levels and have been mined in selected areas along this zone, but the main ore body of the mine occurs around the intersection of this main fault zone with the larger of the flats and the vertical north-striking fault zone. This main ore body is elongate parallel to the dominant northeast-trending fault, but the high-grade ore mined from it was confined to a 25-foot segment near the intersection. This ore body has been selectively mined from the surface to the Bottom level.

Ore of fair grade is exposed in the well-developed and altered fault gouge and breccia under the flat on the Gulch level. Stopes extend as high as 25 feet above the level under the fault from two places in this drift.

Suggestions for Prospecting

The small, discontinuous ore bodies which occur along the northeast-trending fault zone and the larger flat in the Lion Den mine are too erratic to offer favorable chances for further development. Thus, only the intersection of these two faults appears to be likely ground for more minable ore, and it is probable that the main ore body at this intersection does continue for some distance below the Bottom level. No other major structures appear to intersect the northeast-trending fault zone in the mine property and for this reason no other continuous, dependable ore bodies can be foreseen.

Prospects in Silica-Carbonate Rock

Three small prospects explore the east side of the largest silica-carbonate rock body in the central part of the district. The northernmost of these prospects, near the center of the ledge, consists of two adits, each about 6 feet in length, driven into the scarp, and several small, irregular pits which have been quarried out above the adits. The silica-carbonate rock in the vicinity of this prospect is more than normally siliceous and where fresh is especially hard. Cinnabar is rarely observed in these small workings and where present is formed only as painty flecks along fractures. Much of the rock, adjacent to irregular joints and zones of shattering in the ledge, is thoroughly limonitized.

The second prospect is located near the south end of the silica-carbonate rock ledge and consists of an adit about 100 feet in length. The portal is on the steep slope below the fault scarp and most of the tunnel is driven through the contorted strata of the Knoxville formation and fault gouge immediately east of the silica-carbonate rock body. No rock containing enough cinnabar to be considered even low-grade ore is exposed in this prospect.

The third of these prospects is a caved adit located about 200 feet southeast of the southern tip of the silica-carbonate rock outcrop. The size of the dump indicates that the adit is at least 75 to 100 feet in length and is driven to silica-carbonate rock through the Knoxville formation. No ore was found in the silica-carbonate rock on the dump.

Other Prospects and Claims

Lost Chord Claim

The Lost Chord claim lies near the crest of the long spur that trends northwest from Cachuma Mountain, about a third of a mile from the summit (pl. 74). Located in 1930 by J. G. Moore, the claim trends north, with the greater part on the north side of the ridge. The point of original discovery is on a zone of alteration along the prominent northeast-trending fault of the district. In this zone, the Knoxville formation is highly contorted and in places is slightly brecciated and sheared by the fault movement. In addition, the rocks are markedly silicified and carbonatized, and their resultant resistance to weathering has produced a sharp narrow ledge, some 150 feet in length. Although the ledge is remarkably similar to that of the Red Rock mine, no cinnabar was observed by the writer, and apparently no development work has been done on the claim.

Sulphur Dome Claim

The Sulphur Dome claim, half a mile due south of the Red Rock mine, was staked in 1940 by J. W. Warner and F. I. Smith. The claim extends 500 feet northwest and 1,000 feet southeast from the original point of discovery. The "ledge" lies along the southern extension of one of the north-trending set of district faults and is made up of altered sandstone and conglomerate of the Knoxville formation, beds of which strike into the fault at N. 55° W. and dip steeply northeast. As in the Red Rock mine, the alteration is characterized by considerable amounts of hydrothermal massive white soapy clay (dickite?). Moderate carbonatization has also affected the rocks along the fault. No sulfides, mercuric or otherwise, were observed by the writer on this claim, and development work has been confined to one or two very shallow pits.

Placer Deposit

A placer deposit containing cinnabar-bearing gravels was worked for a short period in the summer of 1943 near the southwest end of the large alluvial fan lying to the west of the Lion Den mine. Ecoonmic recovery of quicksilver from this source was not achieved, however, and work on the deposit was discontinued.

Davis Prospect

The Davis prospect, although not located within the Cachuma district, may be considered together with the mines and prospects discussed in this report. The prospect is adjacent to a tributary of Davy Brown Canyon about 5 miles N. 43° W. of the Lion Den mine. The claim was first staked in the 1880's and in the early days of development a quart jar of quicksilver is said to have been produced on the property. Tuffaceous sediments and a thin mafic lava flow are interbedded with strata of the Knoxville formation at the prospect and have been offset by a vertical fault which trends about N. 27° E. Mineralization of the rocks along the fault has given rise to the deposition of small amounts of cinnabar, but that mineral, judging from the shallow pits and exposures on the surface, does not appear to occur in sufficient quantities to constitute even low-grade ore.

SUMMARY AND OUTLOOK

From an economic point of view, the most important geologic structural feature in the Cachuma district is the northeast-trending fault that traverses the rocks of the Knoxville formation from the fault block of the Monterey formation in the central part of the district to the headwaters of Fish Creek in the northeast corner. This fault apparently afforded passageway for the mineralizing hydrothermal solutions which deposited all the cinnabar known in the district. The only silica-carbonate rock bodies in the area occur along the borders of a serpentine sill adjacent to the fault, and the greatest amounts of the rare cinnabar in the silica-carbonate rock occur near the fault zone. This fact, together with the centralization of carbonatized rock around the Red Rock and Lion Den mines, suggests that the carbonate and cinnabar deposition were influenced by the same structural control and may be different phases of the same process. The ore bodies mined at the Red Rock mine were located near the same northeast-trending fault and were richest at the intersections of this fault with other faults. The Lion Den mine and the Lost Chord claim are also located on the same fault. A similar fault 5 miles to the northwest apparently afforded access for the solutions that mineralized the rocks at the Davis prospect.

It is important to note that cinnabar was not deposited in any appreciable amounts where the northeastern fault is the only controlling structural feature. Where the fault intersects another major structural feature, such as an intrusive contact or another strong fault zone, however, cinnabar deposits occur.

In prospecting for new deposits in the Cachuma district and vicinity, it is advisable to look for the intersection of these late northeast-trending faults with other major structures. Apparently no such intersections exist in the area covered by the district map for this report; reconnaissance between the Cachuma district and Figueroa Mountain and Davy Brown Canyon to the west and northwest indicates that none exists in that area. Further mapping to the north, northeast, east, and southeast might disclose such structural features and their intersections, although active prospecting in the area in past years has failed to show any more promising mineralized areas.

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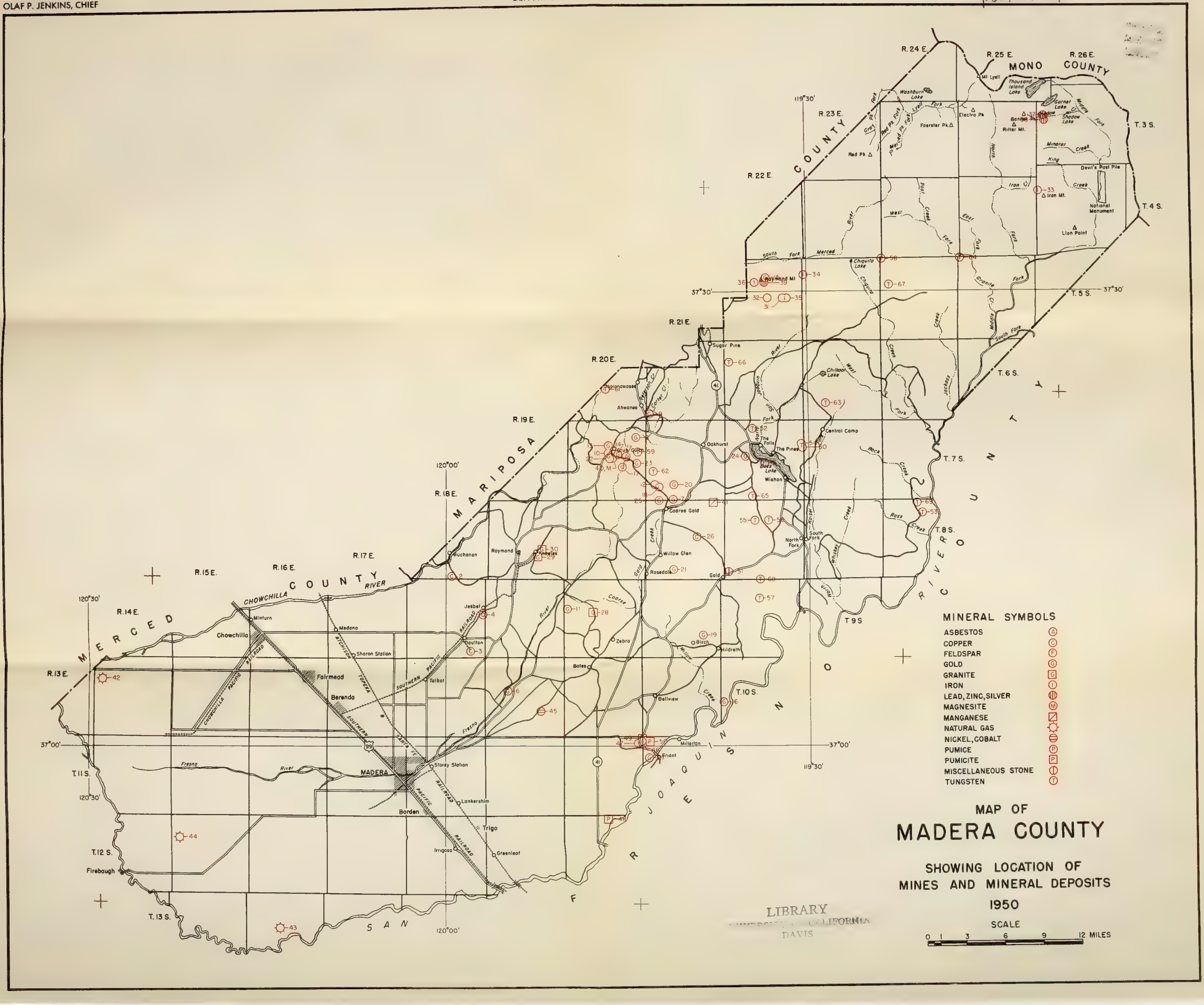
MONO COUNTY
MARIPOSA COUNTY
MERCED COUNTY
FRESNO COUNTY
SAN JOAQUIN RIVER
CHOWCHILLA RIVER
Fresno River
MADERA
Chowchilla
Fairmead
Berenda
Borden
Trigo
Firebaugh
Raymond
Knowles
Coarse Gold
Oakhurst
Ahwahnee
Sugar Pine
North Fork
South Fork
Wishon
Bass Lake
The Pines
Central Camp
Friant
Millerton
Bellview
Hildreth
Zebra
Bates
Daulton
Jesbel
Minturn
Madano
Sharon Station
Talbot
Storey Station
Lankershim
Irrigosa
Greenleaf
Buchanan
Rosedale
Willow Glen
Gold
Birch
Raymond Mt
Iron Mt.
Ritter Mt.
Banner
Electro Pk
Foerster Pk
Red Pk
Mt Lyell
Thousand Island Lake
Garnet Lake
Shadow Lake
Washburn Lake
Chiquito Lake
Chilkoot Lake
Devil's Post Pile National Monument
Lion Point
R.13E.
R.14E.
R.15E.
R.16E.
R.17E.
R.18E.
R.19E.
R.20E.
R.21E.
R.22E.
R.23E.
R.24E.
R.25E.
R.26E.
T.3S.
T.4S.
T.5S.
T.6S.
T.7S.
T.8S.
T9S
T.10S.
T.11S.
T.12S.
T.13S.
119°30'
120°00'
120°30'
37°00'
37°30'
SOUTHERN PACIFIC RAILROAD
ATCHISON TOPEKA & SANTA FE RAILROAD
CHOWCHILLA PACIFIC RAILROAD
99
41

MINERAL SYMBOLS

ASBESTOS	Ⓐ
COPPER	Ⓒ
FELDSPAR	Ⓕ
GOLD	Ⓖ
GRANITE	G
IRON	Ⓘ
LEAD, ZINC, SILVER	⦶
MAGNESITE	Ⓜ
MANGANESE	▧
NATURAL GAS	☼
NICKEL, COBALT	⊖
PUMICE	Ⓟ
PUMICITE	P
MISCELLANEOUS STONE	⦶
TUNGSTEN	Ⓣ

MAP OF
MADERA COUNTY
SHOWING LOCATION OF
MINES AND MINERAL DEPOSITS
1950

SCALE
0 1 3 6 9 12 MILES

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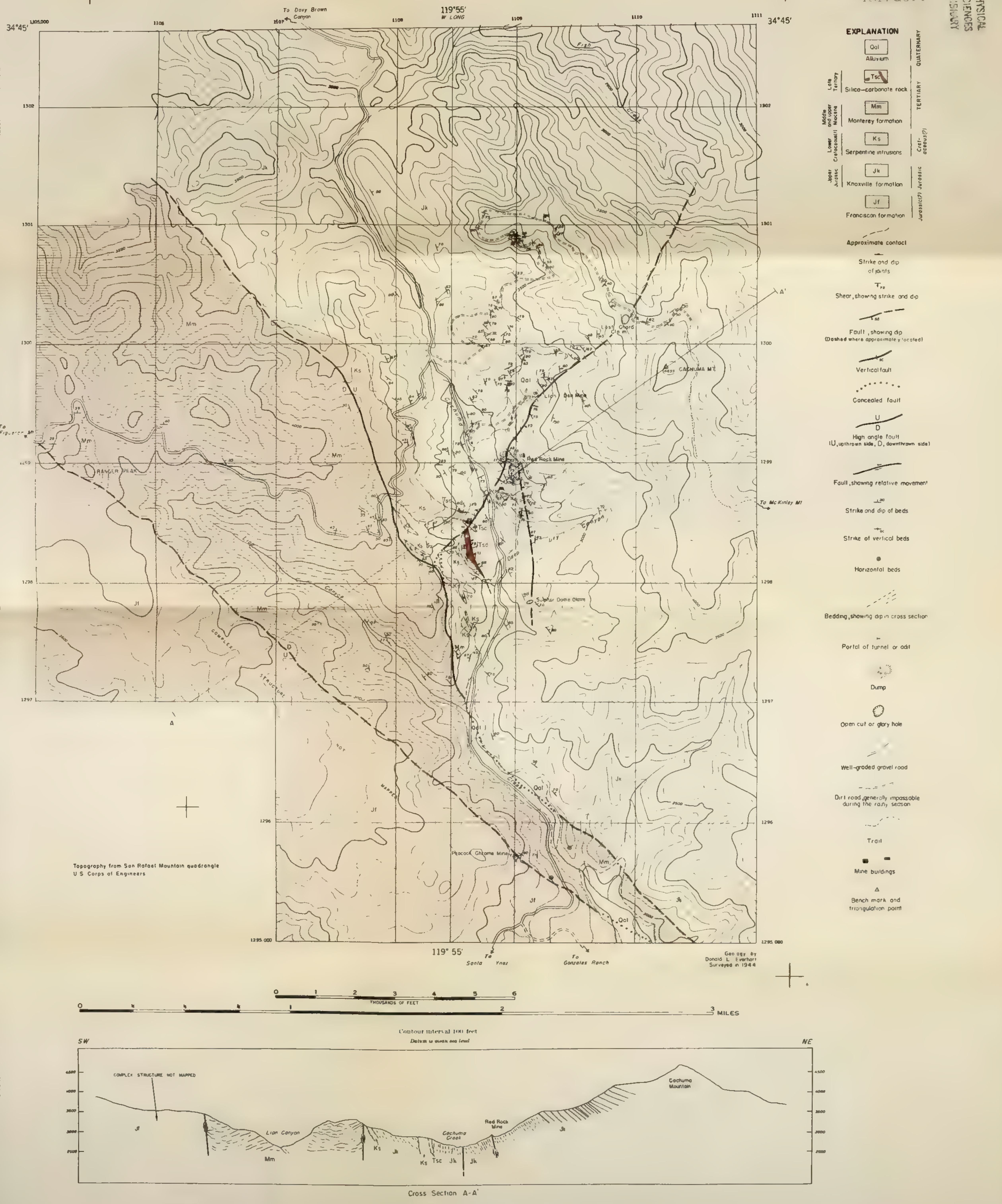
34°45'
119°55'
W LONG
34°45'
To Davy Brown Canyon
Fish Creek
Jk
Mm
Ks
Qal
Tsc
Jf
D
U
Lost Chord Claim
CACHUMA MT.
Lion Den Mine
Red Rock Mine
Sulphur Dome Claim
RANGER PEAK
To Figueroa Mt
To McKinley Mt
Lion Canyon
COMPLEX STRUCTURE NOT MAPPED
Peacock Chrome Mine
A
A'
To Santa Ynez
To Gonzales Ranch
Topography from San Rafael Mountain quadrangle
U.S. Corps of Engineers
Geology by Donald L. Everhart
Surveyed in 1944
119° 55'
EXPLANATION
Qal
Alluvium
QUATERNARY
Late Tertiary
Tsc
Silico-carbonate rock
Middle and upper Miocene
Mm
Monterey formation
TERTIARY
Lower Cretaceous(?)
Ks
Serpentine intrusions
Cretaceous(?)
Upper Jurassic
Jk
Knoxville formation
Jurassic
Jf
Franciscan formation
Jurassic(?)
Approximate contact
Strike and dip of joints
Shear, showing strike and dip
Fault, showing dip
(Dashed where approximately located)
Vertical fault
Concealed fault
High angle fault
(U, upthrown side, D, downthrown side)
Fault, showing relative movement
Strike and dip of beds
Strike of vertical beds
Horizontal beds
Bedding, showing dip in cross section
Portal of tunnel or adit
Dump
Open cut or glory hole
Well-graded gravel road
Dirt road, generally impassable during the rainy season
Trail
Mine buildings
Bench mark and triangulation point
0 1 2 3 4 5 6
THOUSANDS OF FEET
0 1 2 3 MILES
Contour interval 100 feet
Datum is mean sea level
SW
NE
Cachuma Mountain
Red Rock Mine
Cachuma Creek
Lion Canyon
Jf
Mm
Ks
Jk
Tsc
Cross Section A-A'

GEOLOGIC AND TOPOGRAPHIC MAP OF THE CACHUMA QUICKSILVER DISTRICT
SANTA BARBARA COUNTY, CALIFORNIA

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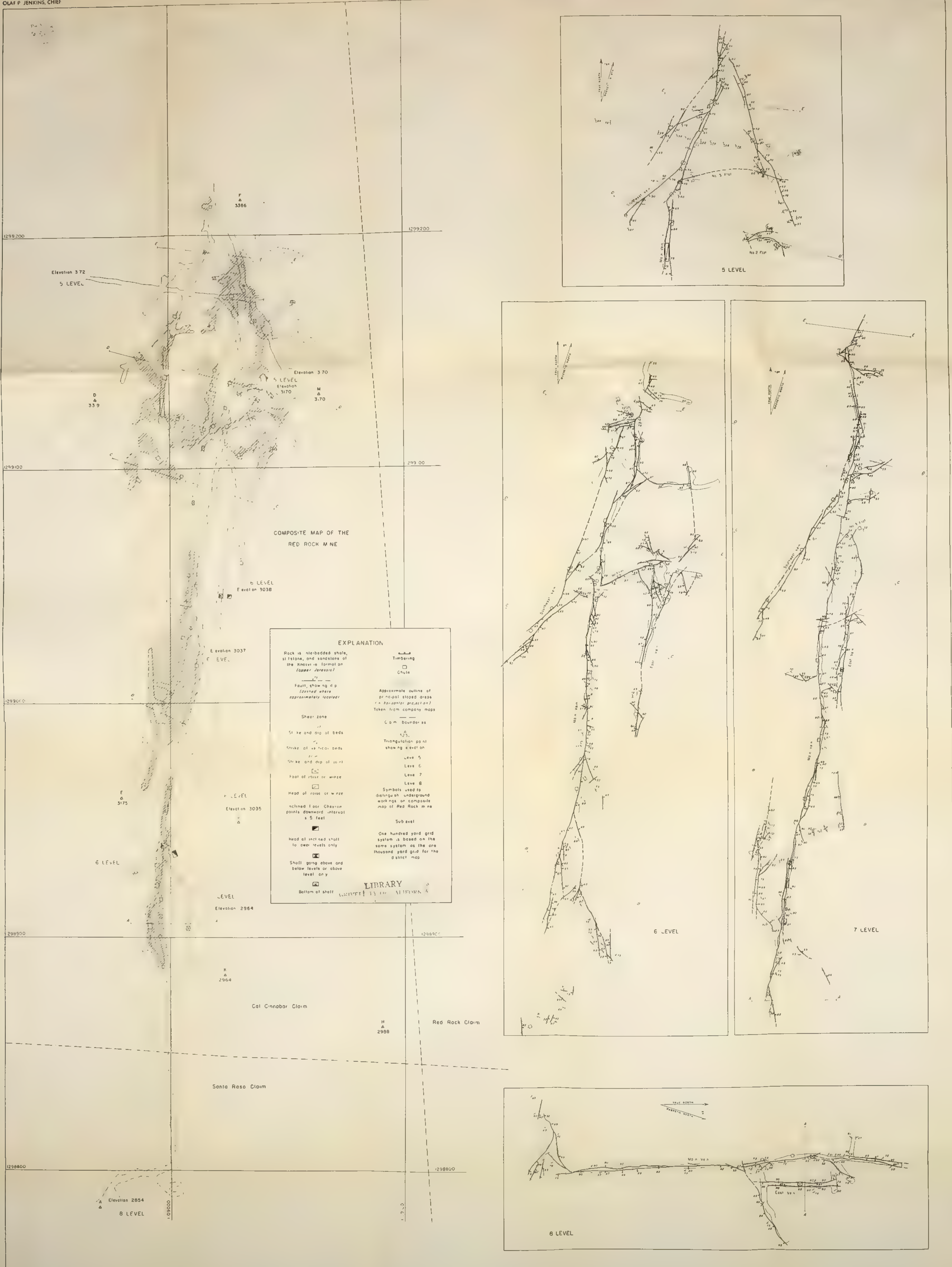
COMPOSITE MAP OF THE
RED ROCK MINE
1298200
1299200
1299100
1299100
1299000
1298900
1298900
1298800
1298800
1090000
F 3366
Elevation 3172
5 LEVEL
Elevation 3170
5 LEVEL
Elevation 3170
M 3170
D 3139
6 LEVEL
Elevation 3038
Elevation 3037
6 LEVEL
E 3175
7 LEVEL
Elevation 3035
6 LEVEL
7 LEVEL
Elevation 2984
K 2964
Cal Cinnabar Claim
H 2988
Red Rock Claim
Santa Rosa Claim
Elevation 2854
8 LEVEL
No 3 Flat
No 2 Flat
Main Vein
Southwest Vein
East Vein
5 LEVEL
6 LEVEL
7 LEVEL
8 LEVEL
TRUE NORTH
MAGNETIC NORTH

EXPLANATION

Rock is interbedded shale, siltstone, and sandstone of the Knoxville formation *(Upper Jurassic)*

Fault, showing dip *(dashed where approximately located)*

Shear zone

Strike and dip of beds

Strike of vertical beds

Strike and dip of joint

Foot of raise or winze

Head of raise or winze

Inclined floor. Chevron points downward, interval is 5 feet

Head of inclined shaft to lower levels only

Shaft going above and below levels or above level only

Bottom of shaft

Timbering

Chute

Approximate outline of principal stoped areas (in horizontal projection) Taken from company maps

Claim boundaries

Triangulation point showing elevation

Level 5

Level 6

Level 7

Level 8

Symbols used to distinguish underground workings on composite map of Red Rock mine

Sublevel

One hundred yard grid system is based on the same system as the one thousand yard grid for the district map

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COMPOSITE AND GEOLOGIC MAPS
OF THE UNDERGROUND WORKINGS OF THE RED ROCK MINE
CACHUMA DISTRICT, SANTA BARBARA COUNTY, CALIFORNIA

B 2913

0 50 100 150 200 250 FEET

Survey and plane table traverse by Donald L. Everhart and J. M. Nelson

Geology by Donald L. Everhart

Surveyed in 1944

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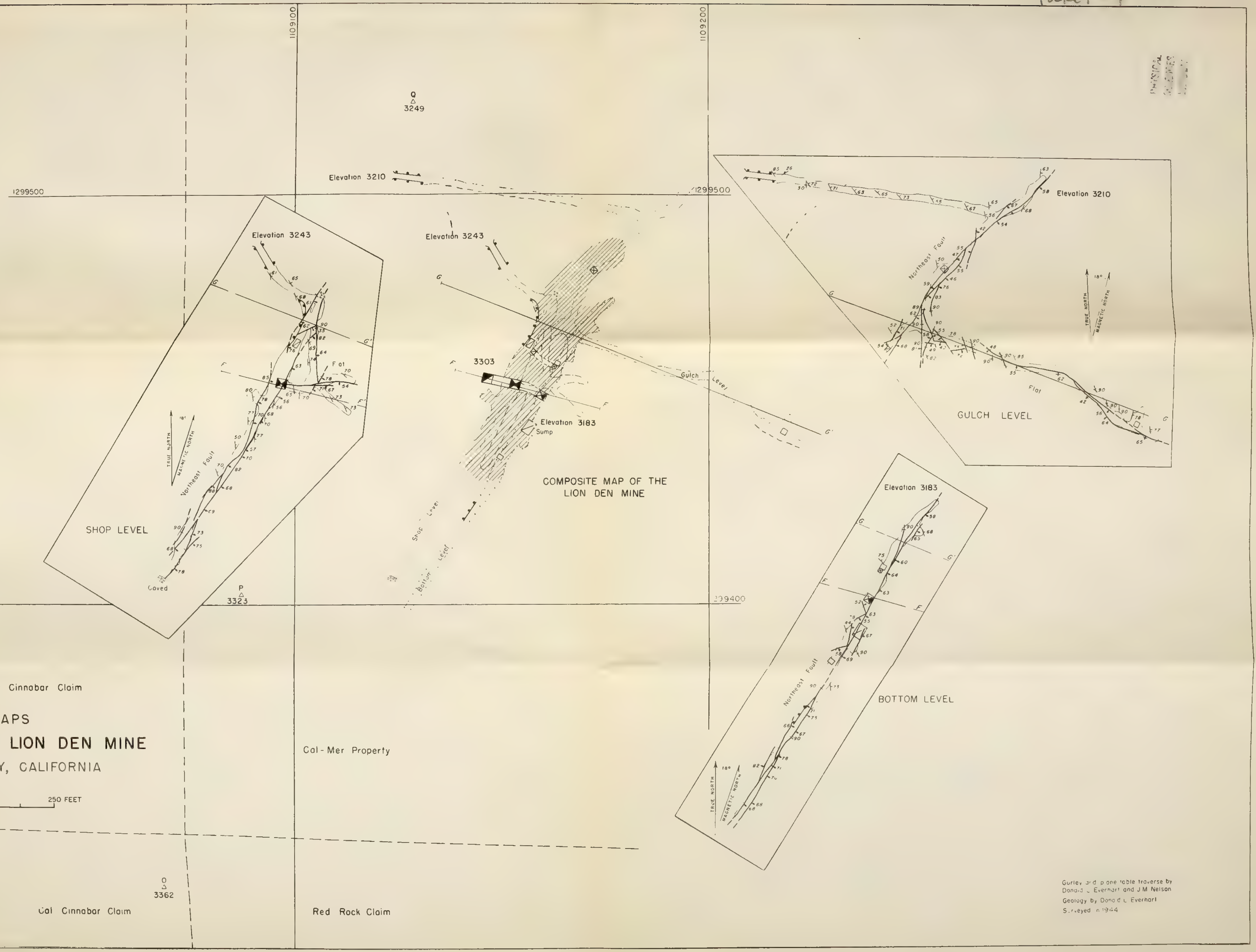
1109100
1109200
1299500
1299400
1109000
Q 3249
Elevation 3210
Elevation 3243
Elevation 3243
Elevation 3210
3303
Elevation 3183
Sump
Gulch Level
Shop Level
Bottom Level
COMPOSITE MAP OF THE LION DEN MINE
SHOP LEVEL
GULCH LEVEL
BOTTOM LEVEL
Elevation 3183
Northeast Fault
Flat
TRUE NORTH
MAGNETIC NORTH
18°
Caved
P 3323
O 3362
Walt Cinnabar Claim
Cal-Mer Property
Cal Cinnabar Claim
Red Rock Claim

EXPLANATION

Rock is interbedded shale, siltstone, and sandstone of the Knoxville formation.
(Upper Jurassic)

Fault, showing dip
(dashed where approximately located)

Shear zone

Strike and dip of beds

Strike of vertical beds

Strike and dip of joint

Foot of raise or winze

Head of raise or winze

Inclined floor
Chevron points downward
Interval is 5 feet

Head of inclined shaft to lower levels only

Shaft going above and below levels or above level only

Bottom of shaft

Timbering

Chute

Approximate outline of principal stoped areas
(in horizontal projection)
Taken from company maps

Claim boundaries

3232
Triangulation point showing elevation

Shop level

Gulch level

Bottom level

Sublevel

Symbols used to distinguish underground workings on composite map of Lion Den Mine

One hundred yard grid system is based on the same system as the one thousand yard grid for the district map

COMPOSITE AND GEOLOGIC MAPS
OF THE UNDERGROUND WORKINGS OF THE LION DEN MINE
CACHUMA DISTRICT, SANTA BARBARA COUNTY, CALIFORNIA

0 50 100 150 200 250 FEET

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Gurley and plane table traverse by
Donald L Everhart and J M Nelson
Geology by Donald L Everhart
Surveyed in 1944

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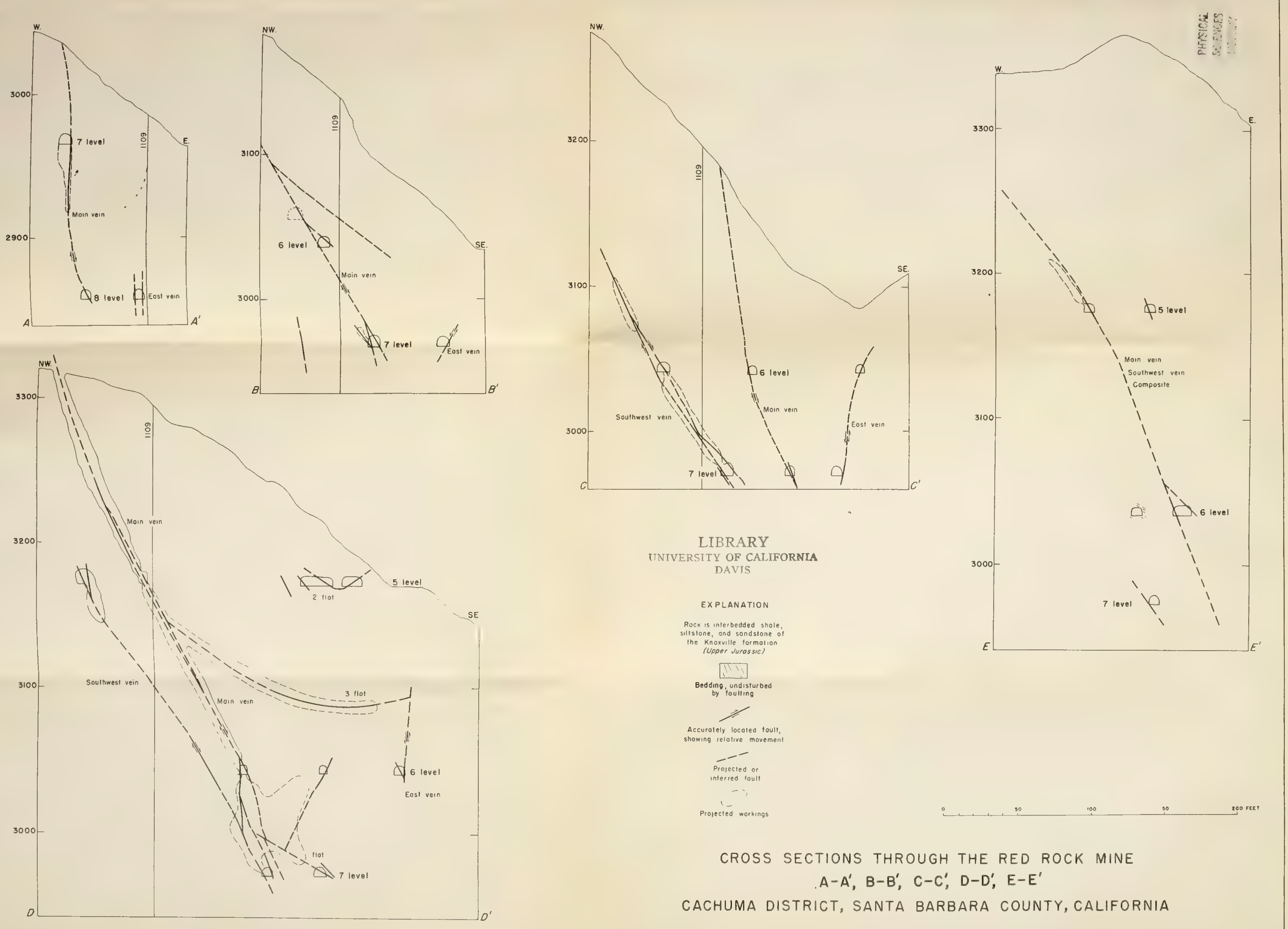
W.
E.
3000
2900
7 level
1109
Main vein
8 level
East vein
A
A'
NW.
SE.
3100
3000
1109
6 level
Main vein
7 level
East vein
B
B'
NW.
SE.
3200
3100
3000
1109
6 level
Main vein
Southwest vein
East vein
7 level
C
C'
W.
E.
3300
3200
3100
3000
5 level
Main vein
Southwest vein
Composite
6 level
7 level
E
E'
NW.
SE
3300
3200
3100
3000
1109
Main vein
5 level
2 flat
Southwest vein
Main vein
3 flat
6 level
East vein
flat
7 level
D
D'
EXPLANATION
Rock is interbedded shale, siltstone, and sandstone of the Knoxville formation (Upper Jurassic)
Bedding, undisturbed by faulting
Accurately located fault, showing relative movement
Projected or inferred fault
Projected workings
0
50
100
50
200 FEET

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CROSS SECTIONS THROUGH THE RED ROCK MINE
A-A', B-B', C-C', D-D', E-E'
CACHUMA DISTRICT, SANTA BARBARA COUNTY, CALIFORNIA

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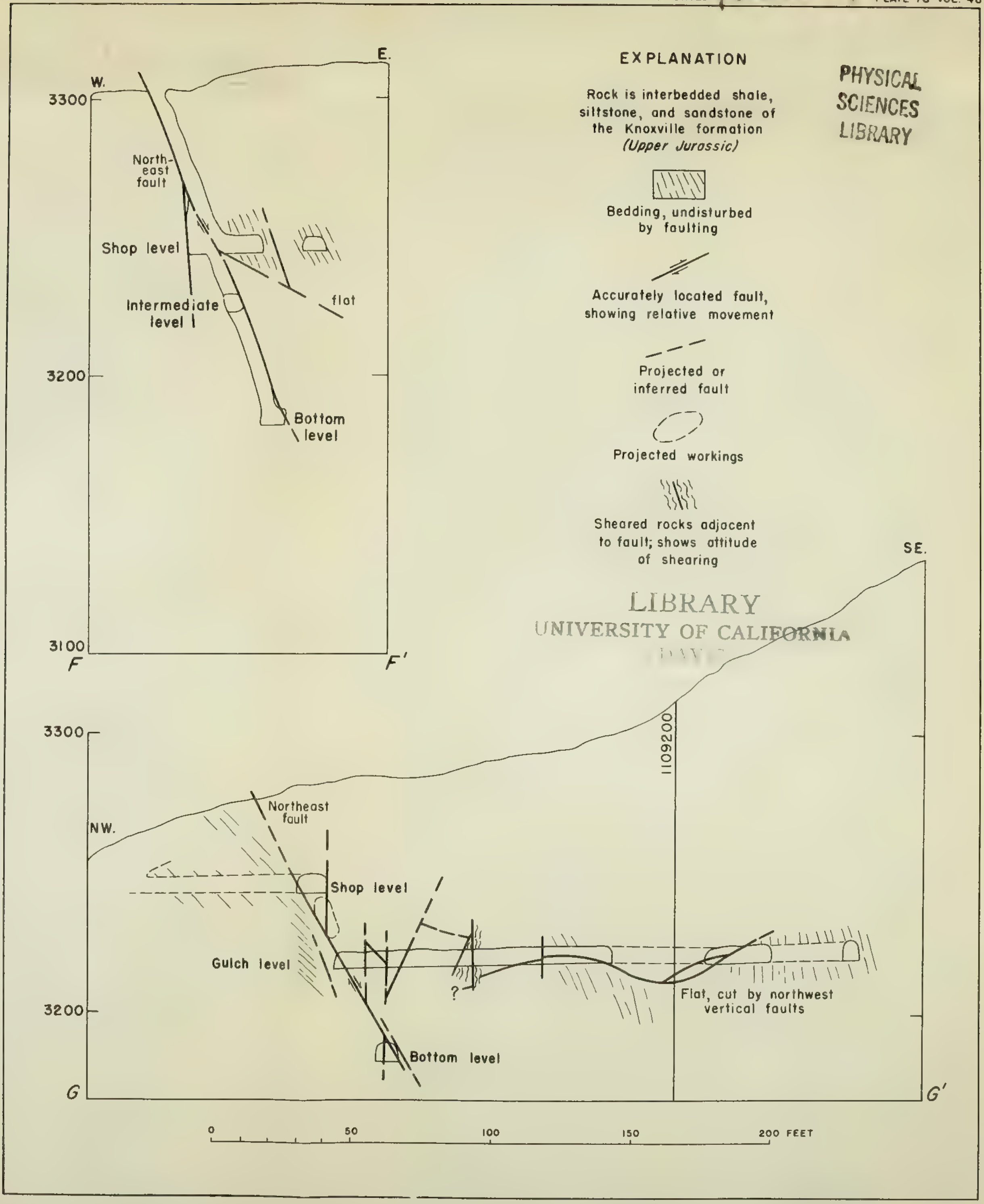
W.
E.
3300
3200
3100
F
F'
North-east fault
Shop level
Intermediate level
flat
Bottom level
EXPLANATION
Rock is interbedded shale, siltstone, and sandstone of the Knoxville formation (Upper Jurassic)
Bedding, undisturbed by faulting
Accurately located fault, showing relative movement
Projected or inferred fault
Projected workings
Sheared rocks adjacent to fault; shows attitude of shearing
SE.
NW.
3300
3200
1109200
Northeast fault
Shop level
Gulch level
?
Flat, cut by northwest vertical faults
Bottom level
G
G'
0
50
100
150
200 FEET

CROSS SECTIONS THROUGH THE LION DEN MINE, CACHUMA DISTRICT, SANTA BARBARA COUNTY, CALIFORNIA

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